BBN REPORT 4743

Community Response to Three Noise Abatement Departure Procedures at John Wayne Airport

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I. INTRODUCTION

The current assessment of community response was conducted as part of an FAA-designed evaluation of the effectiveness of a series of changes in departure procedures at John Wayne Airport. Such changes in aircraft flight procedures are often favored by airport operators and local authorities as means of minimizing noise exposure in communities near airports. It is sometimes asserted that future reductions in community noise exposure levels are likely to come from operational changes (cf. Maglieri and Dollyhigh, 1982). One reason that operational measures, such as preferential runway use and curfews, are attractive is that they usually cost local authorities little. They may also be the only practicable actions, especially if land use planning is politically or economically difficult, or if inherently quieter aircraft equipment is not available.

Reductions in aircraft noise annoyance associated with operational changes are not well documented, however. Fidell and Jones (1973), for example, were unable to find any immediate benefit from institution of nighttime changes in approach paths at Los Angeles International Airport. Hall, Birnie, Taylor, and Palmer (1981) have found that annoyance due to aircraft noise at Toronto International Airport remains widespread despite a four hour rotating runway use system.

One potential reason that major changes in annoyance may not be associated with certain operational changes is that the magnitude of change in noise level is often small. The nighttime approach path changes at Los Angeles International Airport, for example, changed the Day-Night Average Sound Level in affected neighborhoods by less than three decibels.

In practice, it may not be possible to achieve substantial reductions in aircraft noise exposure over a wide area by means of limited operational changes. Changing approach or departure procedures, for example, may reduce community noise levels only along a narrow track, or only at certain distances from the runway, or only at the cost of increasing noise levels in other communities. Substantial changes in flight profiles may also conflict with safety requirements, or may be achievable only under special circumstances at particular airports.

The current study was undertaken to document any potential changes in the prevalence of annoyance in several neighborhoods along the ground track of flights departing John Wayne Airport during the FAA evaluation period.

II. METHOD

A. Nature of Operational Changes

During the months of September and October of 1981, the Federal Aviation Administration organized an evaluation of noise abatement departure procedures at John Wayne Airport in Orange County, California. Air-carrier flights departing John Wayne Airport followed three different noise abatement flight profiles for periods of two or three weeks each during the evaluation. FAA Aviation Safety Inspectors accompanied about one-third of these departures at the beginning and end of each evaluation period. These procedures applied only to the 40-odd daily departures of DC-9 variant and Boeing 737 air-carrier aircraft. More than 500 daily departures by propeller and jet general aviation aircraft at the airport were unaffected.

Figure 1 portrays the three noise abatement departure procedures and the dates they were flown. The majority of the affected departures at John Wayne Airport were Air California and Air West (Republic) operations. For nearly two years prior to the evaluation period, the departure procedures for these two carriers were as follows:

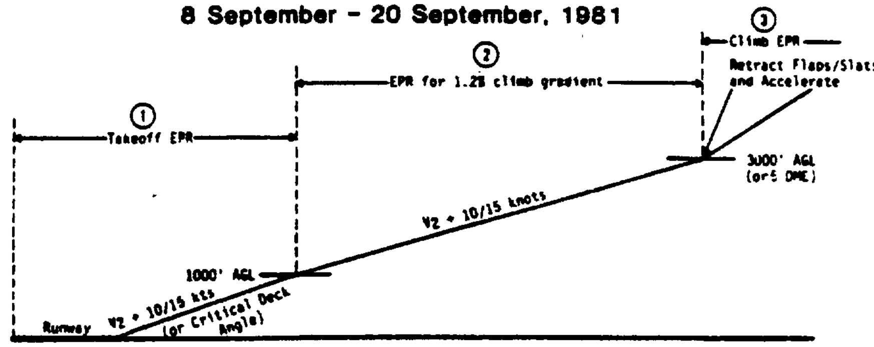
Air California 737 -

Takeoff power and V_2 + 15 knots to 1000 feet
At 1000 feet set 1.7 EPR and maintain speed

Air West/Republic DC9 -

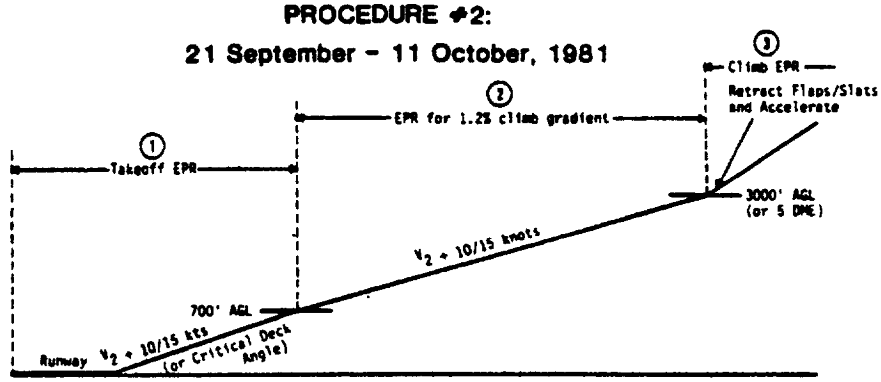
Takeoff power and speed as indicated by speed command
At 1000 feet set climb power and maintain 158 knots
Maintain to 3000 feet.

PROCEDURE #1:
8 September - 20 September, 1981



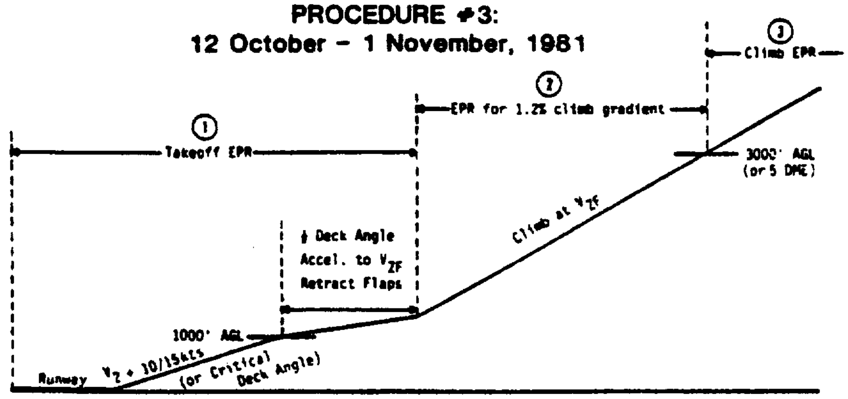
1. Takeoff and climb to 1000' AGL at V_2 + 10/15 knots, using takeoff EPR.
2. At 1000' AGL, reduce thrust to that which will provide a climb gradient of 1.2% at the takeoff gross weight and ambient temperature with the critical engine assume inoperative and no further power input required by the pilot; continue to climb at V_2 + 10/15 knots.
3. At 3000' AGL (or 5 DME), gradually increase thrust to climb power, cleanup and proceed.

PROCEDURE #2:
21 September - 11 October, 1981



1. Takeoff and climb to 700' AGL at V_2 + 10/15 knots, using takeoff EPR.
2. At 700' AGL, reduce thrust to that which will provide a climb gradient of 1.2% at the takeoff gross weight and ambient temperature with the critical engine assume inoperative and no further input required by the pilot; continue to climb at V_2 + 10/15 knots.
3. At 3000' AGL (or 5 DME), gradually increase thrust to climb power, cleanup and proceed.

PROCEDURE #3:
12 October - 1 November, 1981



1. Takeoff and climb to 1000' AGL at V_2 + 10/15 knots at takeoff EPR. At 1000' AGL reduce deck angle to approximately one-half, accelerate to V_{ZF} and retract flaps.
2. After accelerating and retracting flaps at V_{ZF}, reduce thrust to that which will provide a climb gradient of 1.2% at the takeoff gross weight and ambient temperature with the critical engine assume inoperative and no further power input required by the pilot; continue to climb at V_{ZF}.
3. At 3000' AGL (or 5 DME), gradually increase thrust to climb power and proceed.

FIGURE 1. NOISE ABATEMENT DEPARTURE PROCEDURES EVALUATED

The three takeoff procedures differed from one another in two ways: 1) the altitude after takeoff at which power was reduced; and 2) the sequence in which flaps were retracted. All three procedures included a gradual increase in thrust to climb power after passing the shoreline. Power cutbacks at lower altitudes were expected to decrease noise exposure in neighborhoods close to the airport, but to increase noise exposure in more distant neighborhoods. Flap retraction prior to power reduction was expected to further reduce noise exposure in distant neighborhoods, but to increase noise exposure in intermediate neighborhoods.

B. Description of Airport and Community

John Wayne Airport (formerly known as Orange County Airport) is located at Santa Ana in Orange County, California. It is the fourth busiest airport in the United States in number of total aircraft operations. Ninety-one percent of these operations are by propeller airplanes, 6% are by air-carrier jets, and 3% are by general aviation jet aircraft. Due to the prevailing winds, most takeoffs are to the south. Residential areas extend continuously for 3.9 nautical miles from the airport's southern boundary to the Pacific Ocean.

The airport (location identifier SNA) is located at the head of upper Newport Bay, in a suburban area with a population density on the order of 5,000 people per square mile. The population is housed predominantly in detached, single family wood frame structures, most of which have been constructed within the last two decades.

Relations between the airport (a county-owned facility) and the surrounding communities have been marked by litigation in which individuals and groups of residents have sought compensation for and relief from aircraft noise exposure. As recently as 1967, John Wayne Airport had no scheduled jet air-carrier operations. Since then, the number of daily air-carrier operations has steadily expanded. Further planned expansion in airport facilities and commercial operations has been at least temporarily halted by judicial action in a suit (City of Newport Beach vs. County of Orange, et al., Orange County Superior Court Case No. 35-31-01) that was underway at the time of the current evaluation.

C. Selection of Interviewing Areas

Geographic areas affected differentially by the various departure procedures were identified from predicted noise footprints of the commercial air-carrier aircraft, and from annual noise contours. Figure 2 locates these three exposure zones with respect to the airport. Departing flights overfly Newport Bay, roughly bisecting exposure zones 1 and 2, and passing directly over portions of exposure zone 3. Figure 3 shows annual noise exposure gradients across the exposure zones.

Exposure zone 1 is contained entirely within Federal Census Tract 631.01. Exposure zone 2 encompasses portions of Tracts 630.01, 630.02, 630.03, 631.02, and 631.03. Exposure zone 3 contains portions of Tracts 627, 628, 630.01, and 630.02. Figure 4 shows the estimated age/sex distribution for the three interviewing zones. Table I contains information about median annual household income and population density in the three zones.

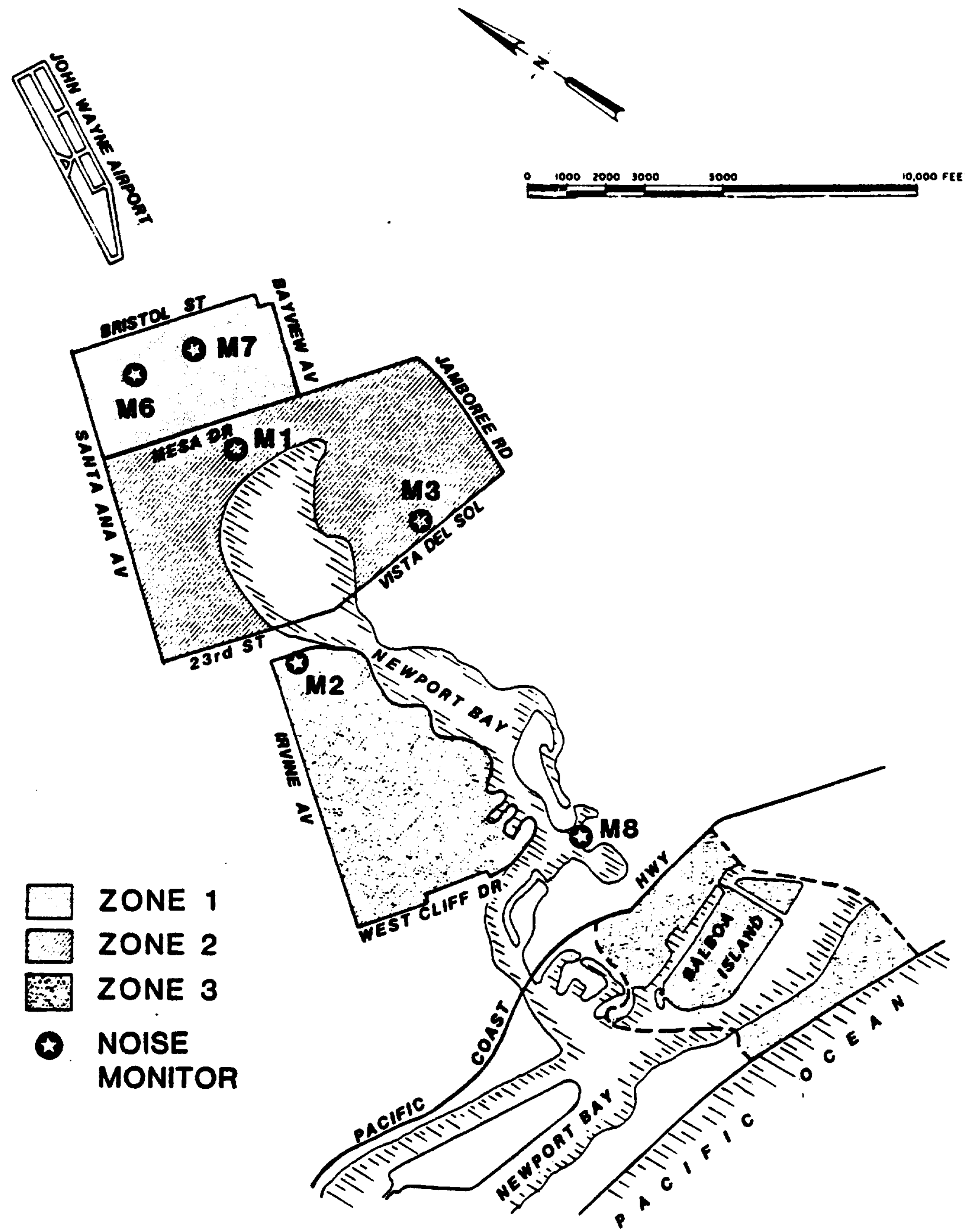
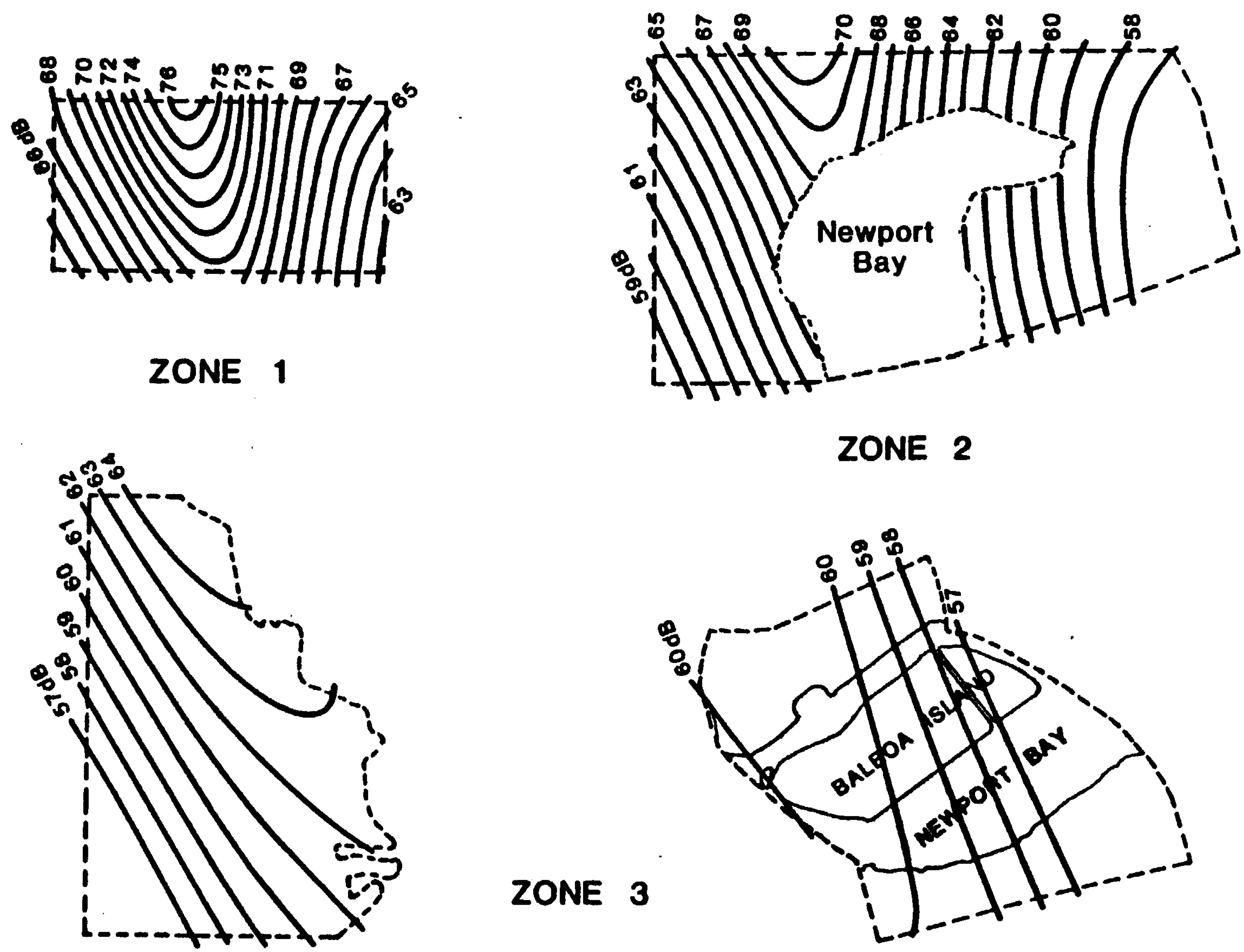


FIGURE 2. LOCATION OF EXPOSURE ZONES WITH RESPECT TO JOHN WAYNE AIRPORT



Approximate Scale: 1" = 3500'

FIGURE 3. COMPUTED ANNUAL L_{dn} CONTOURS FOR THREE EXPOSURE ZONES

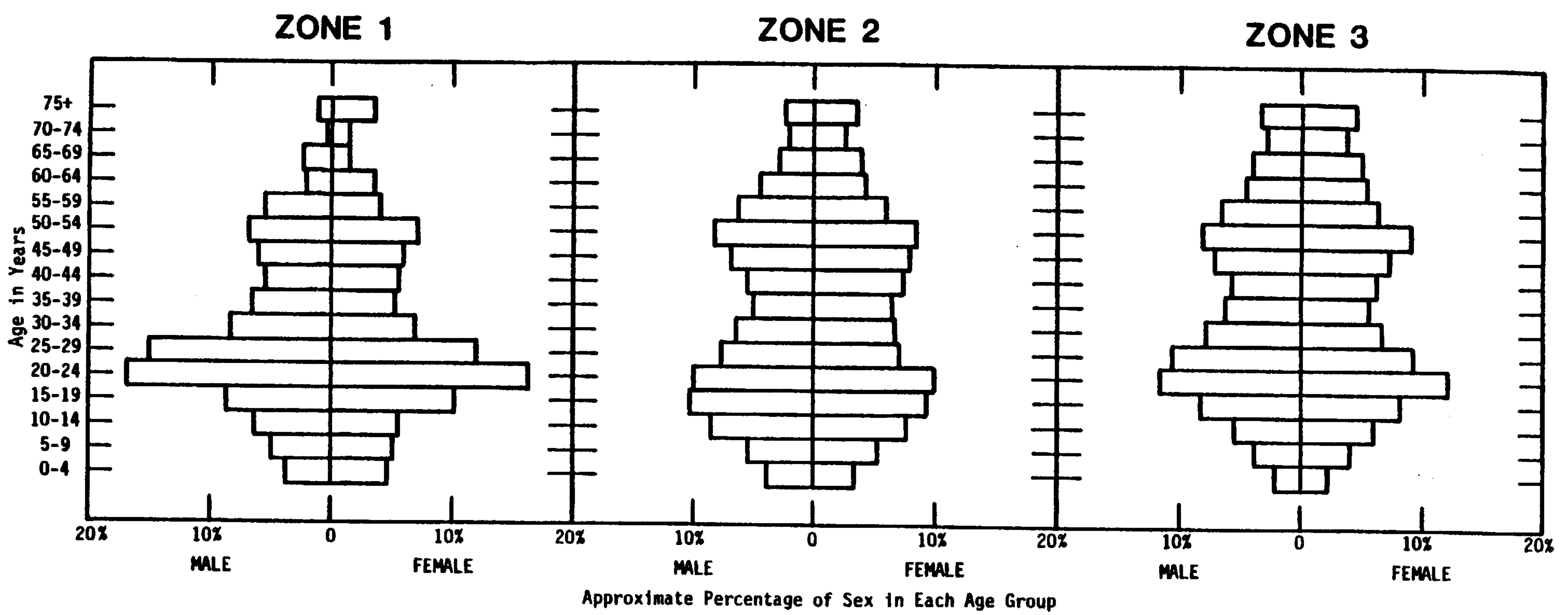


FIGURE 4. AGE AND SEX DISTRIBUTIONS FOR THREE INTERVIEWING AREAS

Exposure Zone	Income[1]	Population Density[2]
1	12100	7.89
2	19700	7.04
3	19100	10.25

1 1975 Median Annual Household Income, in dollars

2 1980 People Per Acre

TABLE I: INCOME AND POPULATION DENSITY INFORMATION FOR INTERVIEWING AREAS

D. Survey Design

1. Interviewing Schedule

An initial round of telephone interviews was conducted during the period 4-6 September, before any changes in departure procedures occurred, to assess the degree of pre-existing annoyance in these three exposure zones. Three subsequent rounds of telephone interviews were conducted during 18-20 September (Round 2), 9-11 October (Round 3), and 30 October-1 November (Round 4). These time periods fell at the ends of two or three week periods of exposure to the departure procedures shown in Figure 1.

Each round of telephone interviewing commenced on a Friday morning and continued through the following Sunday afternoon. Interviews were conducted simultaneously in all exposure zones. Following an initial contact attempt, four additional callbacks were made to each potential respondent at intervals of at least three hours. No more than three callback attempts to a potential respondent were made in any one day.

The decision to terminate additional first contact attempts was made around noon on Saturday, when it became reasonable to expect that adequate numbers of completed interviews would be obtained in all exposure zones. At this point, interviewers were instructed to pursue remaining callback commitments only.

2. Questionnaire

A brief, closed response category questionnaire (Figure 5) was developed to obtain a structured interview. The first

OMB #2120-0104

EXPIRES 12-31-81

ITEM	QUESTION	RESPONSE	CODE
1	How long have you lived on (street name) ?	< 2 weeks < 1 month < 1 year > 1 year Don't Know Not Ascertained Refused	0 1 2 3 7 8 9
2	While you've been at home during the past week, just since last (day of week), have you been bothered or annoyed by street traffic noise? IF YES, ASK: Would you say you've been slightly annoyed by street traffic noise, moderately annoyed by street traffic noise, very annoyed by street traffic noise, or extremely annoyed by street traffic noise?	Not At All Annoyed Slightly Annoyed Moderately Annoyed Very Annoyed Extremely Annoyed Don't Know Not Ascertained Refused	0 1 2 3 4 7 8 9
3	While you've been at home during the past week, have you been bothered or annoyed by the noise of little propeller airplanes? IF YES, ASK: Would you say you've been slightly annoyed by noise from little propeller airplanes, moderately annoyed, very annoyed, or extremely annoyed by noise from little propeller airplanes?	Not At All Annoyed Slightly Annoyed Moderately Annoyed Very Annoyed Extremely Annoyed Don't Know Not Ascertained Refused	0 1 2 3 4 7 8 9
4	While you've been at home during the past week, have you been bothered or annoyed by the noise of large airliners? IF YES, ASK: Would you say you've been slightly annoyed by noise from large airliners, moderately annoyed, very annoyed or extremely annoyed by noise from large airliners?	Not At All Annoyed Slightly Annoyed Moderately Annoyed Very Annoyed Extremely Annoyed Don't Know Not Ascertained Refused	0 1 2 3 4 7 8 9
5	While you've been at home over the past year, since last (season of year), have you been bothered or annoyed by the noise of large airliners? IF YES, ASK: Would you say you've been slightly annoyed by noise from large airliners, moderately annoyed, very annoyed, or extremely annoyed by noise from large airliners?	Not At All Annoyed Slightly Annoyed Moderately Annoyed Very Annoyed Extremely Annoyed Don't Know Not Ascertained Refused	0 1 2 3 4 7 8 9

FIGURE 5. QUESTIONNAIRE ITEMS AND CODING CATEGORIES

item was a screening question to verify eligibility of respondents. Item 2 was included to assess the observed prevalence of annoyance due to a non-aircraft source of community noise exposure that was expected to remain constant in level throughout the evaluation period. Item 3 was included for similar reasons, since noise from aircraft other than scheduled commercial airliners was not expected to vary appreciably. The question also called attention to the distinction between types of aircraft affected by the departure procedure changes and those that were unaffected during the evaluation period.

Item 4 posed the question of principal interest. The time frame ("during the past week") of the item was selected to focus attention on a period of consistent duration during which the most recent departure procedure had been in effect. Item 5 repeated the question of Item 4 for a longer time period ("over the past year"). Questioning about long term annoyance was included to collect information about the relationship of short term fluctuations in annoyance to long term attitudes.

As a procedural matter, the order of mention of response category labels was counterbalanced over the interviews. Half of the interviews (Form 1) were conducted mentioning the labels in the order "Not at all annoyed"... "Extremely annoyed", while the other half (Form 2) were conducted in the opposite order.

3. Sampling Strategy

a. Sampling Frame

Street address boundaries for the three exposure zones of Figure 2 were determined from detailed local maps. All blocks within these boundaries were listed, and eligible street addresses identified. Residential telephones in the exposure zones were compiled into a sampling frame derived from the August 1981 edition of the Pacific Telephone Street Address Telephone Directory for Orange County. Telephone subscription is essentially universal in the interviewing areas.

The numbers of residential telephone subscribers listed in separate households were approximately 550, 1200, and 4000 in exposure zones 1, 2, and 3, respectively. Because the populations of interest varied in size, different sampling ratios were employed in the different exposure zones to obtain comparable sample sizes. The sampling ratios for households were approximately 1:2, 1:3, and 1:10 in exposure zones 1, 2, and 3, respectively.

This sampling strategy produced independent samples for each round of interviewing in exposure zone 3. However, because the population sizes were relatively small in exposure zones 1 and 2, partial panel samples were the de facto result of the large sampling ratios in these zones.

b. Sample Size Determination

The principal consideration in determining sample size was the resolution desired in discriminating changes in the prevalence of annoyance associated with changes in noise exposure produced by different departure procedures. Secondary considerations included the sizes of the populations available for sampling in the three exposure zones, and available project resources. The reasoning by which the desired sample size was established is described below. As with all such reasoning, simplifying assumptions were made to avoid paralysis in dealing with certain imponderables. These assumptions included: 1) that a monotonic and approximately linear function relates the prevalence of annoyance to noise exposure; and 2) that exposure-related effects predominate over other potential sources of variability in generating annoyance.

A recent survey conducted at a nearby airport (Fidell et al., 1981), with exposure levels and a community relations history comparable to those at John Wayne Airport, provided the most direct guidance. In this survey, the dosage-response curve (relating the proportion of the community highly annoyed to the Day-Night Average Sound Level (L_{dn})) had a slope of 1:.03. In other words, for every one decibel increase in L_{dn}, an additional .03 of the community described itself as highly annoyed by aircraft noise. The changes in departure procedures of current interest were expected to produce exposure level changes ranging from about 3 to 6 dB in different exposure zones at different times. Associated proportions of the residential populations highly annoyed by these changes were thus expected to change by about .09 to .18.

If the exposed populations are dichotomized into proportions highly annoyed by aircraft noise and proportions not highly annoyed by aircraft noise, 95% confidence intervals for the proportions can be estimated from the binomial distribution as $\pm 1.96(PQ/N)^{1/2}$, where P is the proportion highly annoyed, Q is its complement, and N is the number of respondents. Under worst case assumptions ($P = Q = 0.5$), the 95% confidence interval is ± 0.069 for an N of 200.

Using the normal approximation to binomial probabilities, the significance of the difference betwen two independent proportions can be estimated as

$$Z = (P_1 - P_2)/(P_1Q_1/N_1 + P_2Q_2/N_2)^{1/2}.$$

Z is a standardized score for a Gaussian distribution with a mean of zero and a variance of 1. Areas under this "normal probability" curve are tabulated by Z scores to permit estimates of the likelihood of occurrence of events governed by Gaussian processes. Since 95% of the area under the normal curve lies below a Z score of 1.6, events associated with normal deviates yet more extreme would be expected to occur only 5% of the time by chance alone.

Thus, if the difference in proportions of the community observed to be highly annoyed by aircraft noise in two rounds of interviewing were as little as 0.08 (say, .50 and .58), the odds that such a difference could arise from random factors alone would be only 1 in 20. In other words, with a sample of 200 respondents in each exposure zone in each round of interviews, the survey could be expected to be sensitive to changes in the prevalence of annoyance associated with noise exposure changes on the order of 2-3 dB.

This degree of resolution and confidence in the findings of the current survey was acceptable, affordable, and realizable in the three exposure zones of interest.

E. Interviewers

Approximately twenty interviewers were trained to administer the Questionnaire. Each read a training manual detailing procedures to be followed in the interviews. The manual stressed objectivity and accuracy rather than speed in executing the interviewing. Interviewers were paid at an hourly rate. All practiced administering the Questionnaire during a training session, and had to satisfactorily interview supervisors before starting. Each individual interviewer's calls were equally distributed among the three exposure areas. All interviewing was accomplished under supervision from a central calling location.

F. Noise Measurements

Budgetary considerations restricted noise exposure measurements to those routinely produced by the existing monitoring system installed at John Wayne Airport. The basic datum available from each of the six microphone positions was the daily L_{dn} value. These figures were energy-averaged over week-long periods preceding each round of interviews. These values were interpreted with the aid of noise contours to estimate area-weighted noise exposure levels for each of the interviewing areas. The area-weighting procedure, described in greater detail in Appendix A, was designed to represent noise exposure levels throughout the interviewing areas more adequately than would single point measurements.

III. RESULTS

A. Compliance with Departure Procedures

FAA Aviation Safety Inspectors were onboard 270 (12%) of the jet air carrier departures during the evaluation period. Inspectors rode on approximately one-third of the departures at the beginning and end of each evaluation period, and on a smaller fraction of the flights at intermediate times.

The inspectors' reports provided information on the consistency with which the procedures were flown, and also on takeoff weights. Figure 6 shows the distribution of takeoff weight by aircraft type. A sub-scale indicates approximate information on the variation in the ground projection of the flight track location where power reduction was initiated.

Figures 7 through 9 show the distribution of observed climb speeds prior to power reduction and the distribution of power reduction altitudes. Sub-scales indicate the approximate variation in the flight track location where power reduction was initiated, as a function of these parameters. Figure 7 also shows the distribution of the observed EPR after power reduction, in relation to the target EPR for the desired flight profile. A sub-scale indicates the approximate variation with EPR of the noise level under the flight track.

These figures do not include data for the first week (8-14 September), during which inspectors reported considerably greater variation in flight parameters than during the remaining seven weeks. Except for the first week, the distributions were relatively uniform.

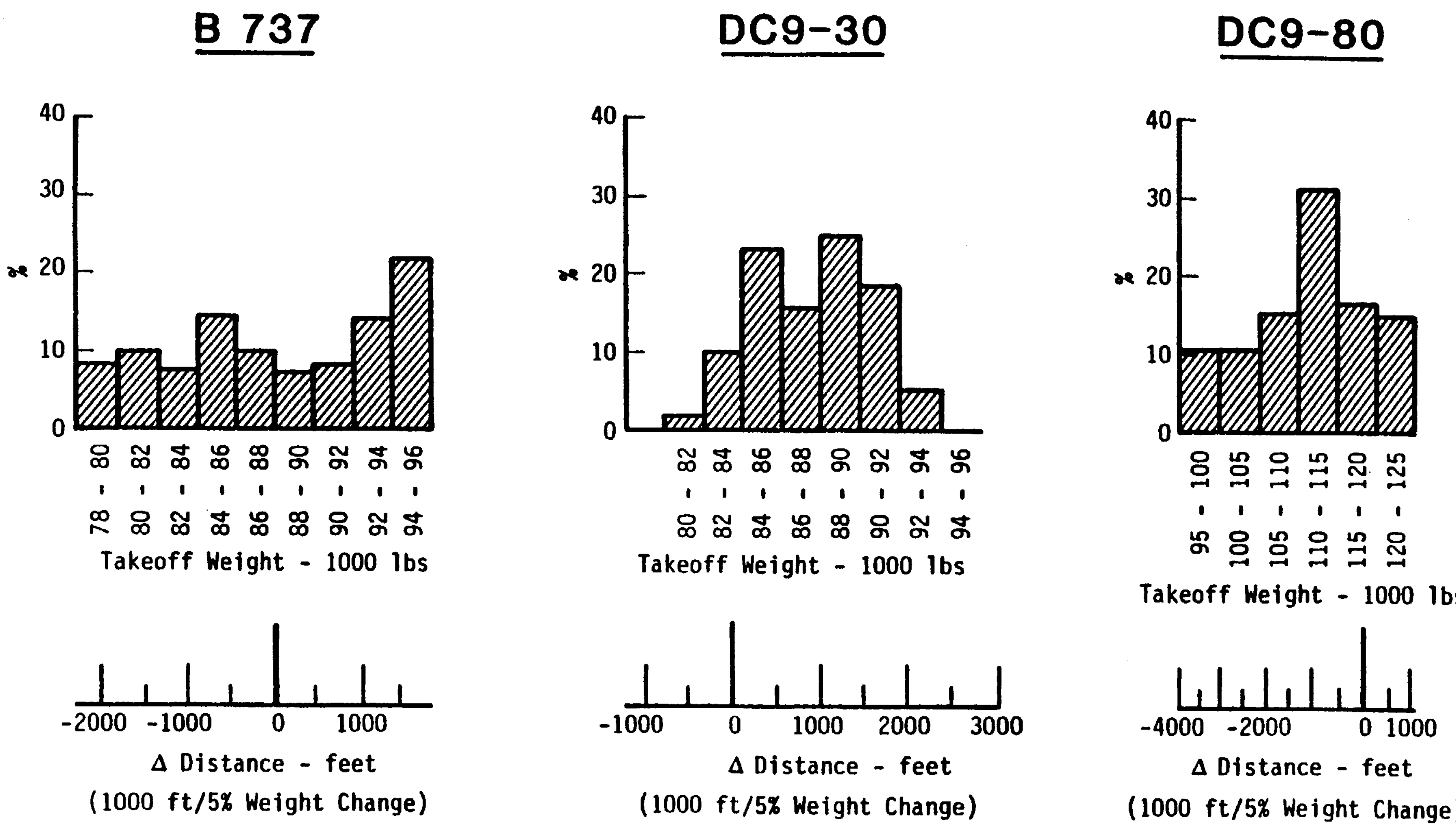


FIGURE 6. TAKEOFF WEIGHT DISTRIBUTION

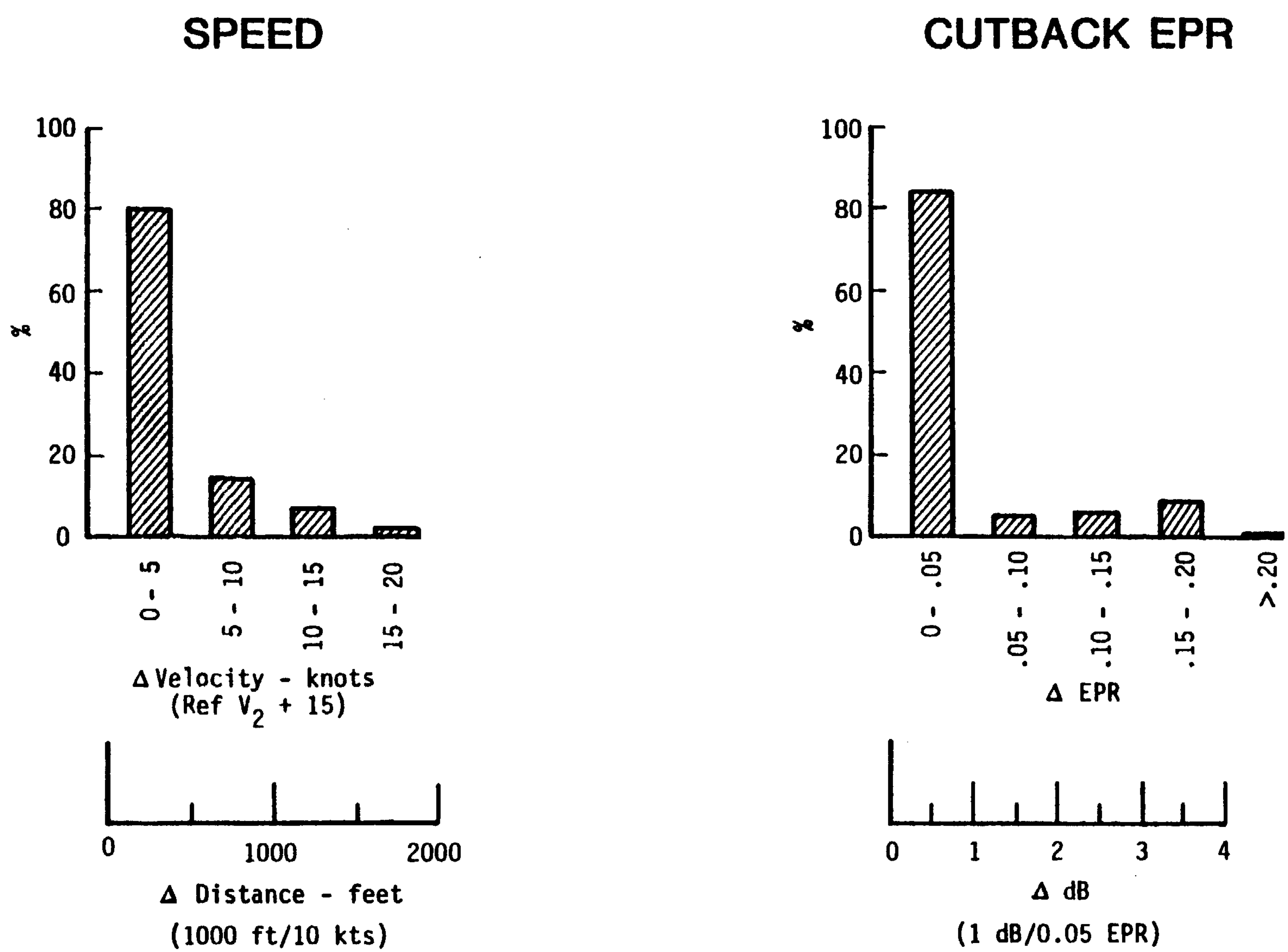


FIGURE 7. SPEED AND CUTBACK POWER DISTRIBUTIONS

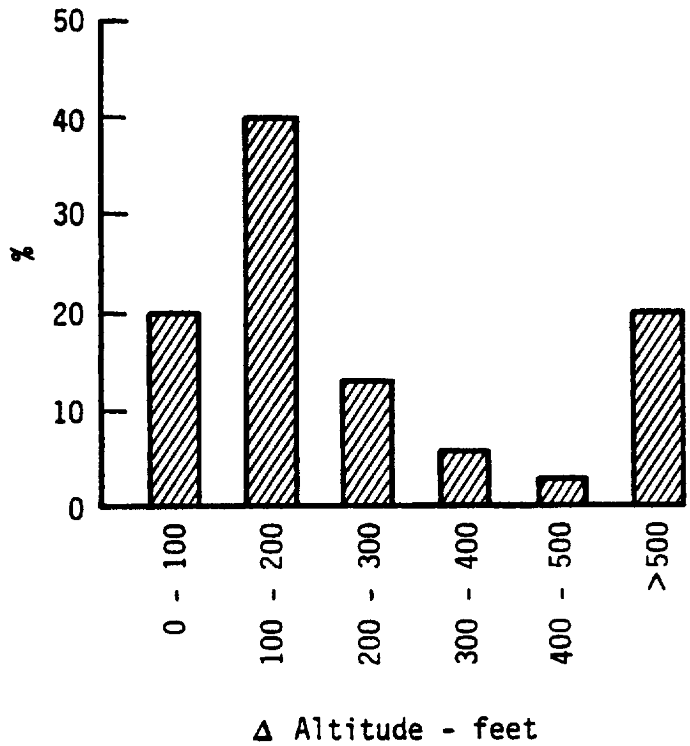


FIGURE 8. DISTRIBUTION - ALTITUDE GAIN TO COMPLETE POWER REDUCTION

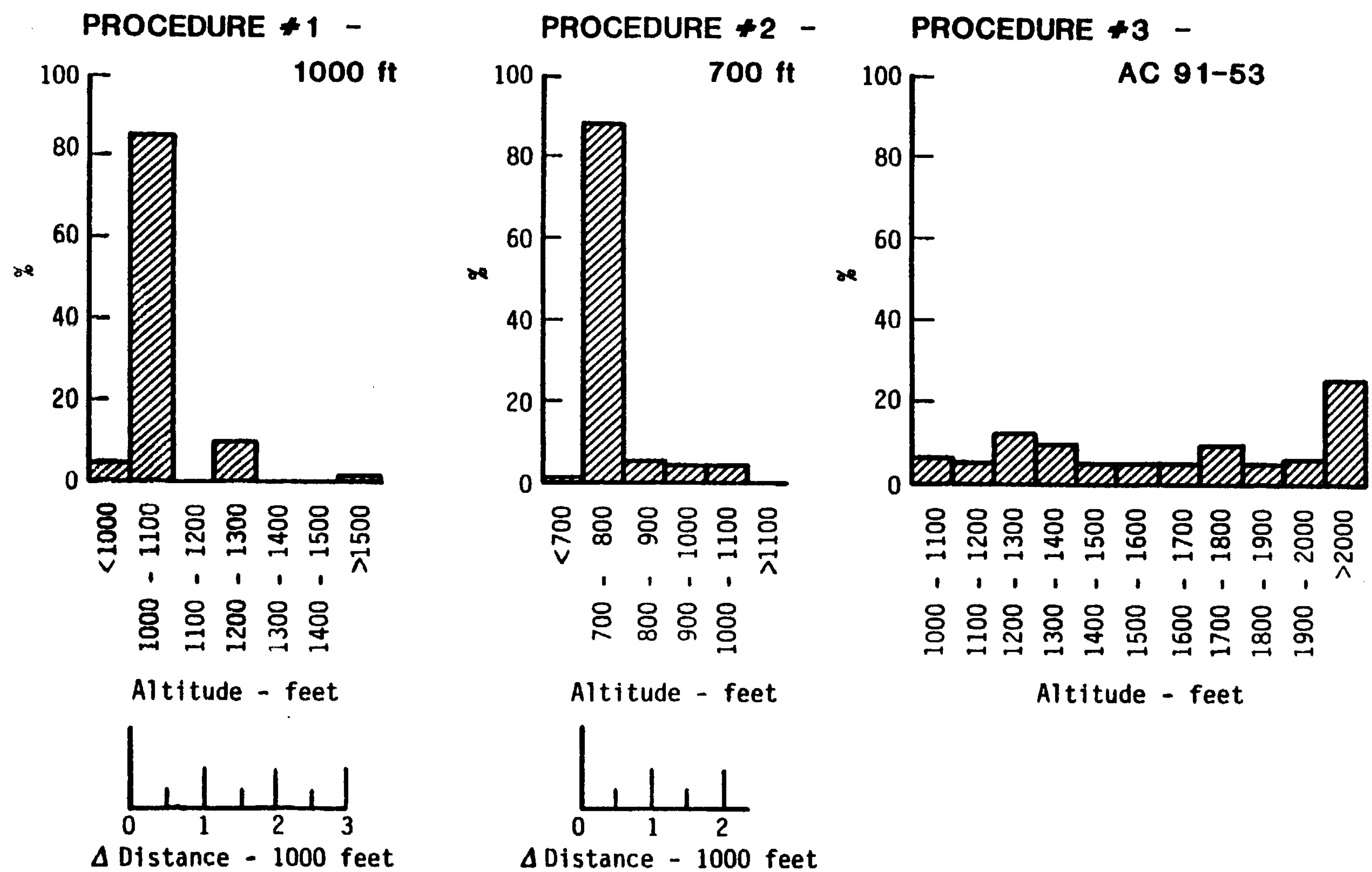


FIGURE 9. DISTRIBUTION - ALTITUDE POWER REDUCTION STARTED

Although most flights complied well with individual flight parameters, considerable variability is also apparent in Figures 7 through 9. Boeing 737 aircraft took off at weights ranging from 78,000 to 96,000 pounds; DC-9-30s at 80,000 to 96,000 pounds; and DC-9-80s at 95,000 to 125,000 pounds. These differences in takeoff weight inevitably led to differences in flight profiles, and hence, ground level noise exposure.

Furthermore, over half of the departures monitored by FAA personnel exceeded at least one of the following flight parameter values:

a. more than V_2+20 knots climb speed prior to power reduction

b. more than 100 feet altitude higher than the target power reduction altitude

c. more than 200 feet altitude gain to complete power reduction

d. more than 0.05 over the target power reduction EPR.

Since ground level noise exposure is determined primarily by slant range and engine power settings, the net result of this variability in flight parameters was to reduce the differences in noise exposure associated with the different departure procedures. As a result, differences in noise exposure throughout the evaluation period were not as great as had been anticipated.

Noise Exposure Measurements

Aircraft noise exposure measurements were made continuously throughout the evaluation period at the six microphone positions identified in Figure 2. Two uses were made of these data, as indicated below.

1. Confirmation of Effects of Changes in Departure Procedures

Maximum A-weighted sound levels during individual overflights by each of the aircraft types affected by the procedural changes were examined for time periods corresponding to the 1000' and 700' power cutbacks at one microphone position. The intent of this examination was to determine whether the operational changes did in fact produce the expected pattern of changes in ground level noise. One of the microphone positions at which the expected changes were reflected most clearly was the airport's position 7, quite close to the departure end of the runway. Figure 10 compares the distributions of maximum A-weighted levels for individual flights for the three major air-carrier aircraft.

Note that for each aircraft type, the distributions of maximum A-weighted levels are shifted toward lower levels during the 700' power cutback period relative to the 1000' period. Although the (energy) means of each of these pairs of distributions differ by only about 3.5 dB, it is readily apparent that large percentages of departures during the 700' power cutback created maximum levels 6 dB or more lower than during the 1000' power cutback.

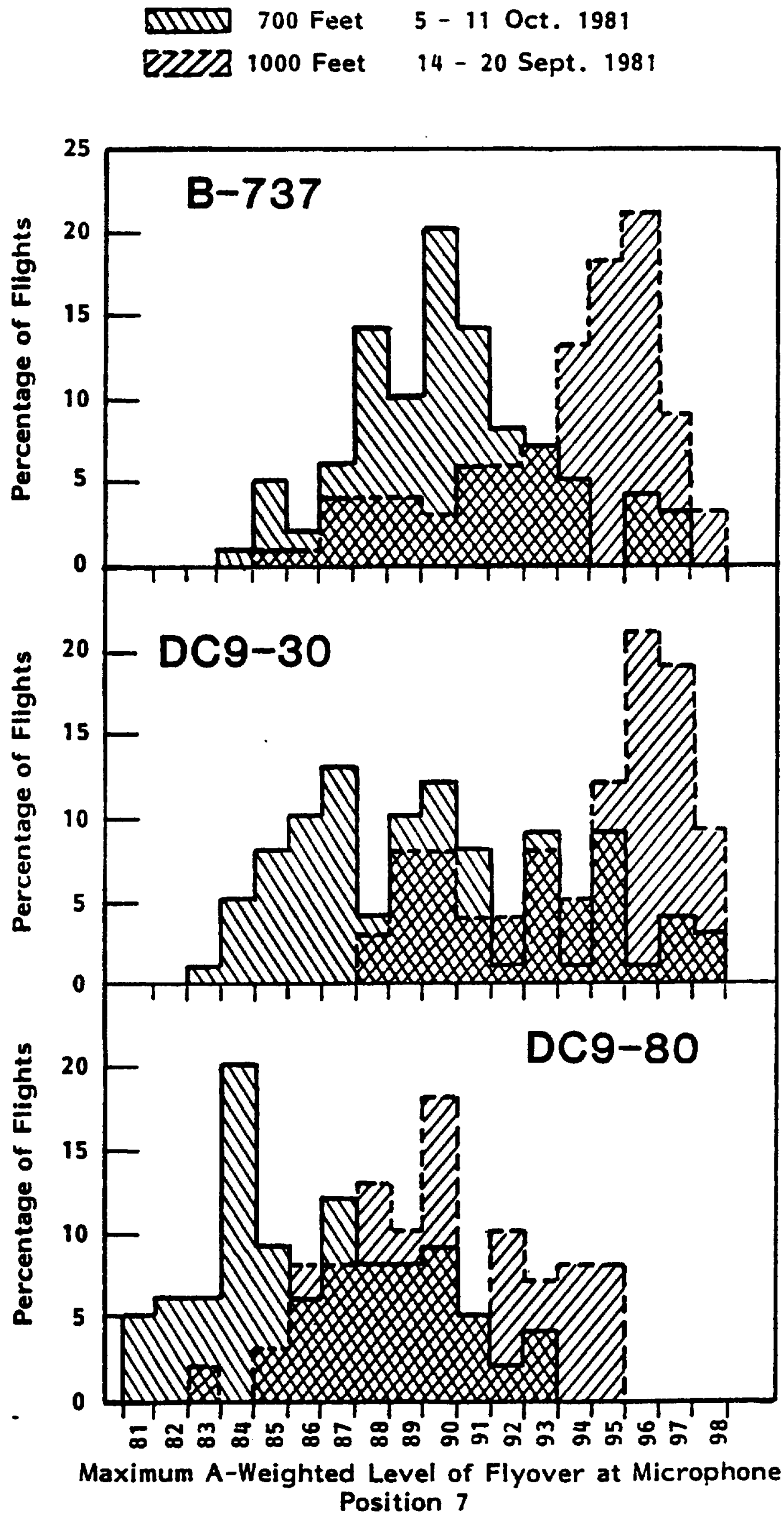


FIGURE 10. COMPARISON OF DISTRIBUTIONS OF MAXIMUM A-WEIGHTED LEVELS OF FLYOVERS FOR TWO DEPARTURE PROCEDURE

2. Area-Weighted Noise Exposure in Interviewing Areas

Table II displays area-weighted estimates of L_{dn} for one week periods preceding each round of interviews, developed by the procedures outlined in Appendix A. Exposure values were highest in the interviewing area nearest the airport, lower in the intermediate area, and lowest in the area farthest from the airport. The direction of change in exposure level was also generally consistent: lower in areas nearer the airport for lower altitude power cutbacks; higher in nearer and intermediate areas during the period in which Advisory Circular 91-53 procedures were flown.

The magnitudes of the changes in area-weighted exposure level, however, were all smaller than had been expected. Table III compares the changes in area-weighted aircraft noise exposure estimates (relative to the week prior to the start of the current evaluation) with a measure of the usual weekly fluctuations in exposure levels at nearby microphone positions. The statistic that expresses the usual fluctuations (attributable to minor changes in schedules, weather conditions, and operating conditions) is the standard deviation of weekly L_{dn} values, as calculated over a ten month period preceding the current evaluation.

Changes in exposure from week to week as great as ± 1 standard deviation would be expected to occur 68% of the time in the normal course of events at John Wayne Airport. Thus, the intentionally produced exposure changes of roughly ± 1 dB are comparable to those which have historically occurred from week to week at John Wayne Airport under routine conditions.

	Exposure Zone 1	Exposure Zone 2	Exposure Zone 3
Week Prior to Start of Evaluation	67.1	61.8	59.0
Week Prior to Interviews Concerning Departure Procedure 1	67.1	61.3	58.6
Week Prior to Interviews Concerning Departure Procedure 2	65.3	60.5	59.1
Week Prior to Interviews Concerning Departure Procedure 3	68.1	63.4	58.1

TABLE II

ESTIMATED AREA-WEIGHTED NOISE EXPOSURE LEVELS
IN WEEKS PRECEDING INTERVIEWING

	Zone 1	Zone 2	Zone 3
Week Prior to Start of Evaluation	0 dB	0 dB	0 dB
Week Prior to Procedure 1	0	-0.5	-0.4
Week Prior to Procedure 2	-1.8	-1.3	+0.1
Week Prior to Procedure 3	+1.0	+1.6	-0.9
Standard Deviation of Weekly Exposure 10/80-8/81	1.2	1.1	1.2

TABLE III. CHANGES IN AREA-WEIGHTED L_{DN} (IN dB RE LEVEL DURING WEEK PRIOR TO FIRST ROUND OF INTERVIEWS) IN RELATION TO VARIABILITY IN WEEKLY AIRCRAFT NOISE EXPOSURE AT MICROPHONE POSITIONS NEAR THREE INTERVIEWING AREAS.

C. Social Survey Findings

More than 3100 interviews were completed in the three exposure zones during the course of four rounds of interviewing. Appendix B provides a standard accounting for the mechanics of interviewing and tabulates the raw data. Substantive findings are presented in order of questioning in the following subsections. Other procedural findings of the survey are discussed in Appendix C.

1. Responses to Questionnaire Item 2

Respondents were requested in Item 2 to describe their annoyance with local street traffic noise at their residences during the week preceding each round of interviews. They were permitted to use only the following terms for this description: not at all annoyed, slightly annoyed, moderately annoyed, very annoyed, or extremely annoyed.

Figure 11 plots the percentages of respondents who described themselves as highly annoyed (either "very" or "extremely" annoyed) by the street traffic noise in each round of interviews against the estimated level of traffic noise exposure in their neighborhoods. The positions of the plotting symbols on the abscissa indicate residual (non-aircraft) noise exposure levels calculated by the airport's monitoring system in the weeks before each round of interviews. Since these values are not necessarily unbiased estimates of street traffic noise in the interviewing zones, ranges are also plotted for each symbol to show alternate estimates of ambient noise levels in each interviewing area. These alternate estimates are based on actual

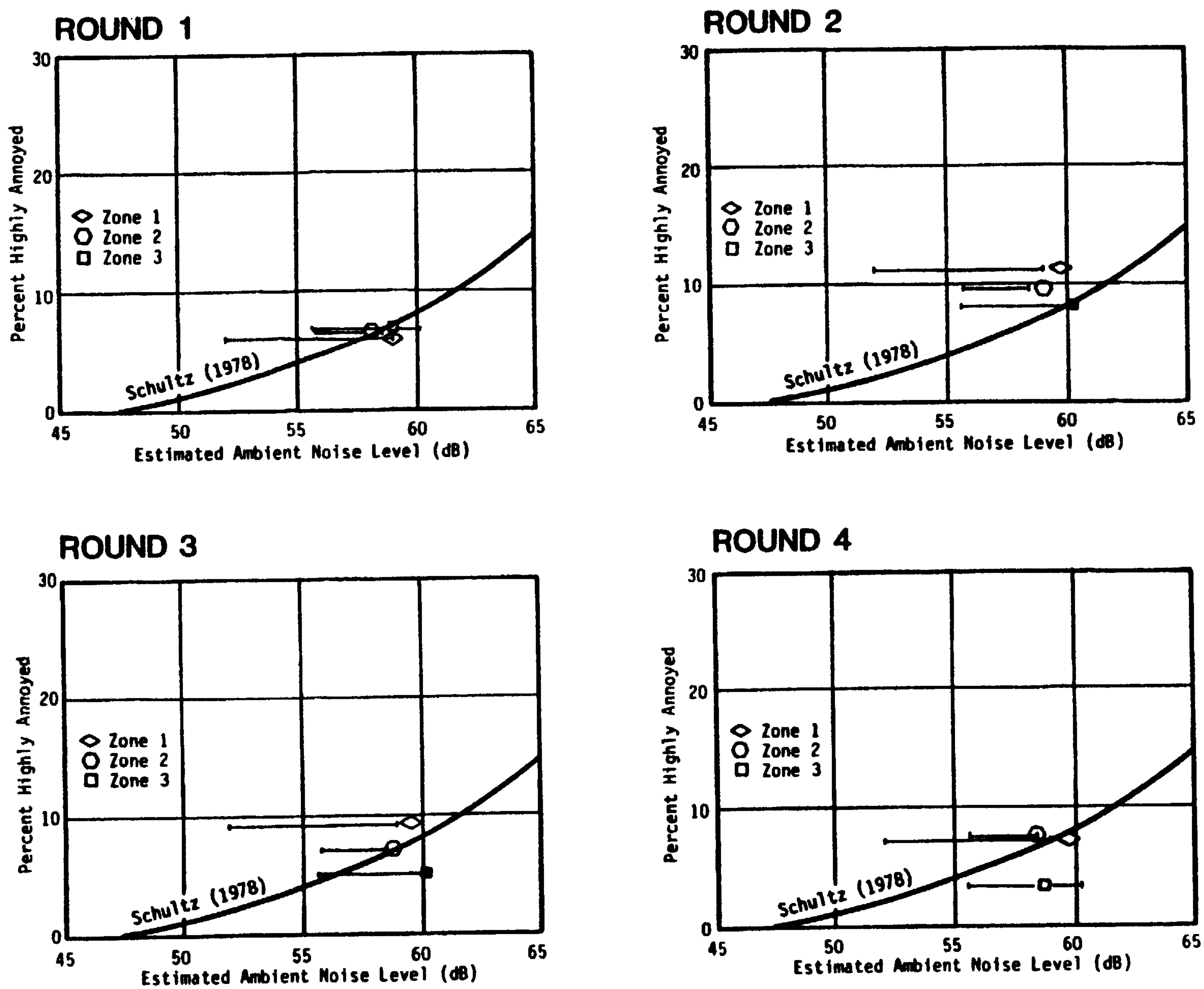


FIGURE 11. ANNOYANCE DUE TO STREET TRAFFIC NOISE

measurements made in these areas at other times (cf. Bishop and Simpson (1973) and Simpson (1974)), and upon noise exposure levels predicted from population density (Galloway, Eldred, and Simpson (1974)). The latter estimate is given by

$$L_{dn} = 10 \log \rho + 22 \text{ dB},$$

where ρ is the population density in people per square mile.

The curve that may also be seen in Figure 11 is a portion of a general dosage-response relationship synthesized by Schultz (1978) from the data of numerous social surveys conducted in several countries. The curve, described as "the best currently available estimate of public annoyance due to transportation noise of all kinds", is given by

$$\% \text{ Highly Annoyed} = 0.8553\, L_{dn} - 0.0401\, L_{dn}^{2} + 0.00047\, L_{dn}^{3}$$

Two aspects of Figure 11 are noteworthy. First, there were no appreciable changes in either the percentages of respondents highly annoyed by street traffic noise or in the noise itself from round to round of interviews. Second, the observed values of noise exposure and annoyance due to street traffic noise closely resemble those observed in other social surveys conducted elsewhere. Two reasonable inferences that may be drawn from these findings are: 1) that the present survey techniques yield data interpretable in conformity with data on the prevalence of annoyance observed elsewhere; and 2) that the communities surveyed are not unusually sensitive to one common form of noise exposure.

2. Responses to Questionnaire Item 3

Respondents were requested in Item 3 to describe their annoyance with noise produced by propeller driven light aircraft heard while at home in the week preceding interviewing. Figure 12 plots the proportions of respondents who described themselves as highly annoyed by such noise. This information is not plotted against noise exposure because the airport's monitoring system was not designed to quantify exposure produced by light aircraft.

Two observations may be made about responses to Item 3 nevertheless. First, the patterns of annoyance did not change appreciably during the evaluation period, nor did the numbers of propeller aircraft operations change. The average numbers of daily departures by aircraft unaffected by the current evaluation were 575, 558, 516, and 516 for the weeks prior to the four rounds of interviews. Second, the prevalence of annoyance due to propeller aircraft noise is considerably smaller than that due to noise from jet airliners (see below).

The pattern of prevalence of annoyance in the three zones is readily interpretable. Exposure zone 1, immediately off the end of the runway, is the area subjected to the greatest number of overflights by light aircraft. Thus, it is not surprising that the proportion of respondents highly annoyed by light aircraft is generally greatest in this exposure zone. Since flight tracks of general aviation aircraft disperse to the northwest and southeast in the region of exposure zone 2, it is overflown by fewer light aircraft, and at greater altitudes. Because there are few destinations for light aircraft on the bearing of zone 3 from

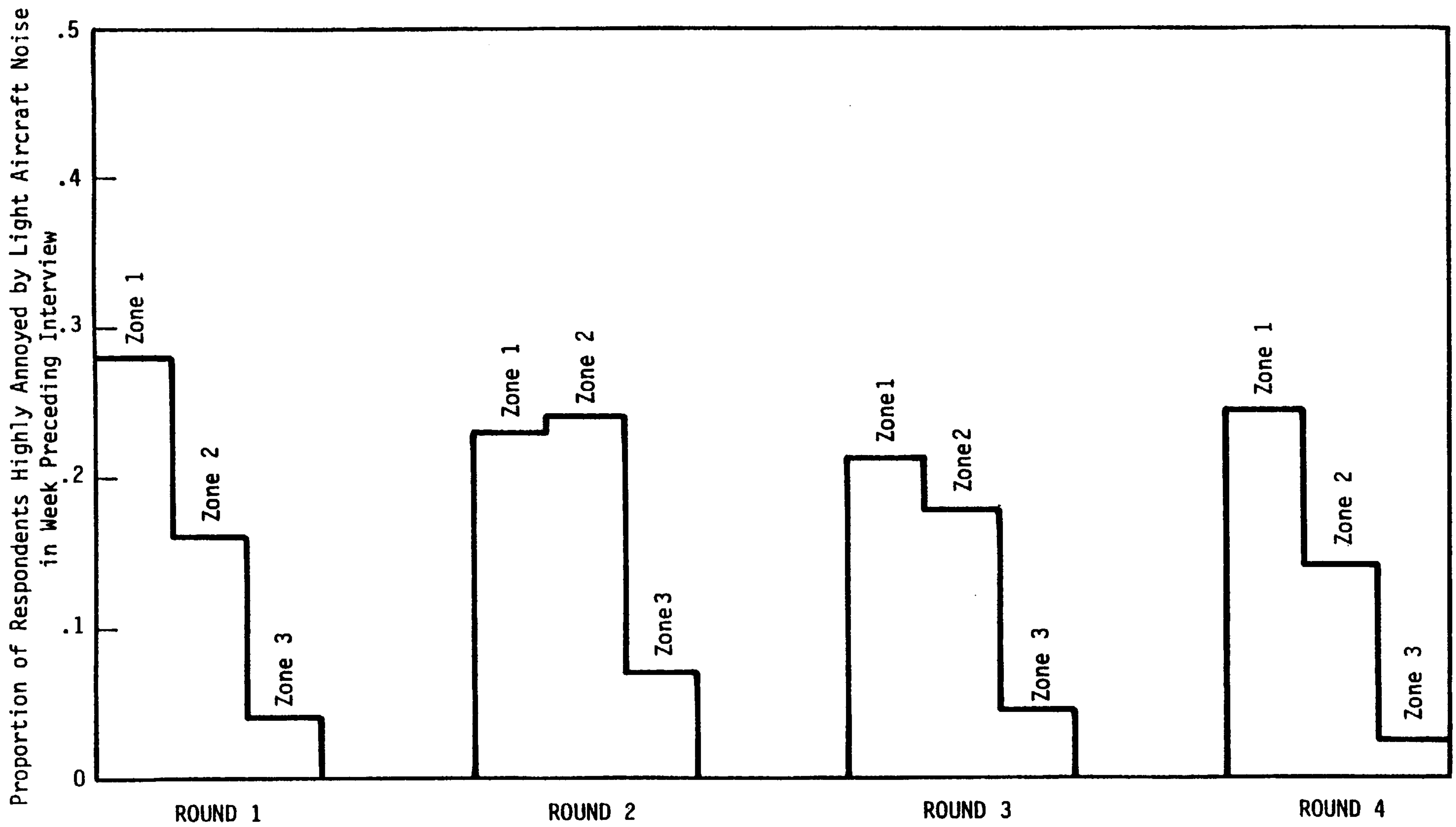


FIGURE 12. ANNOYANCE DUE TO PROPELLER AIRCRAFT NOISE

John Wayne Airport, and because the few overflights are at greater altitudes and often at lower power settings than in zones 1 and 2, noise exposure due to light aircraft in this zone is lower than in the other zones. This pattern of light aircraft noise exposure is clearly reflected in the diminishing proportions of respondents highly annoyed by light aircraft noise in zones 1 to 3.

3. Responses to Questionnaire Item 4

Respondents were requested in Item 4 to describe their annoyance with air-carrier aircraft noise in the week preceding each round of interviews. Figure 13 is a plot of the percentages of respondents who reported that they were highly annoyed, versus the area-weighted noise exposure estimates of Table II.

The statistical association between prevalence of annoyance and noise exposure across interviewing areas and rounds of interviews is quantified by the least squares regression plotted as a dashed line in the figure. The correlation between exposure and annoyance ($r = 0.88$) is very unlikely to have arisen by chance alone.

The present data are considerably displaced from Schultz's dosage-effect relationship, plotted as a solid curve in the lower right portion of Figure 13. The mismatch is either 15 dB (for equivalent prevalence of high annoyance) or about 30% (for equivalent noise exposure).

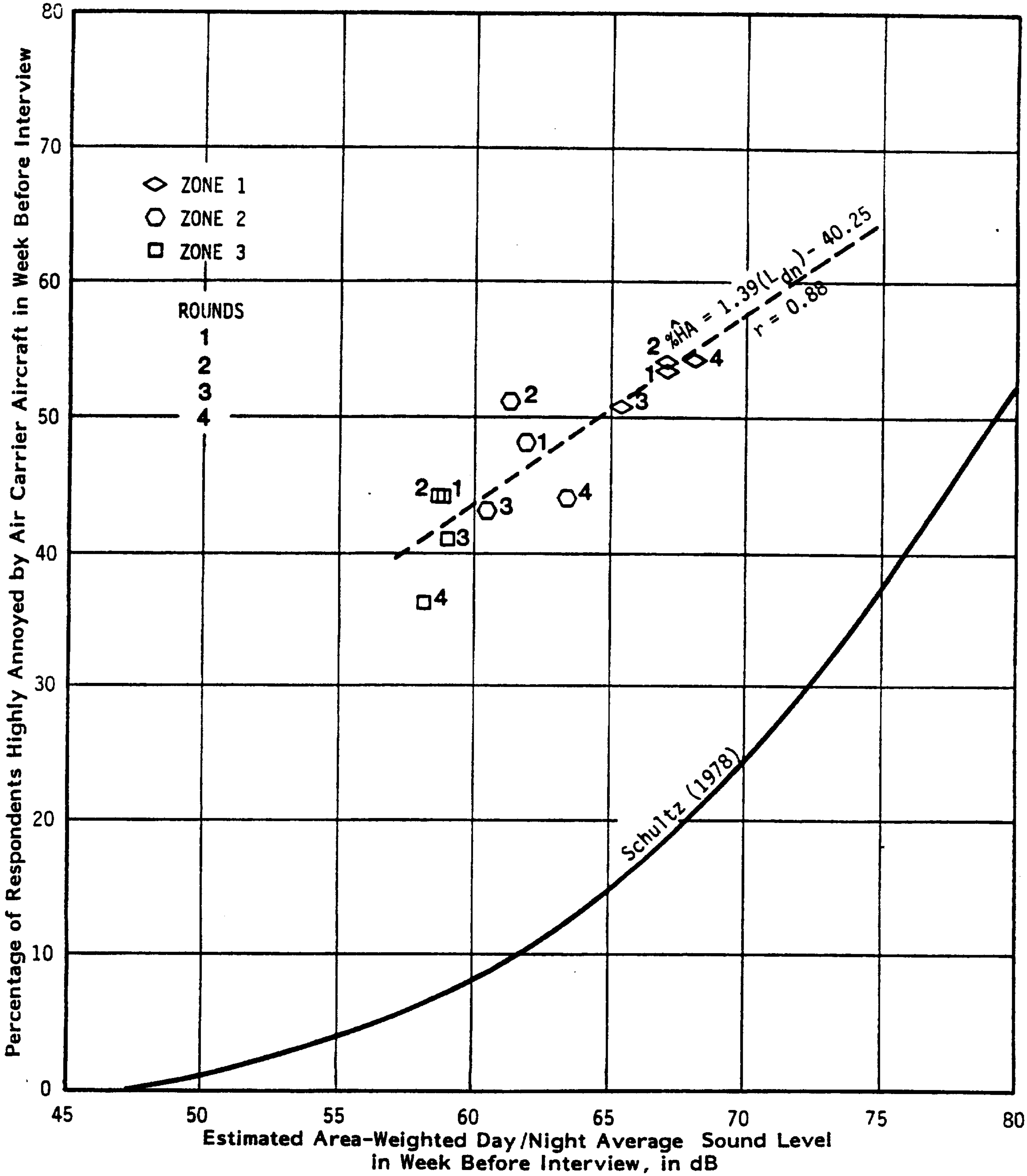


FIGURE 13. RELATIONSHIP BETWEEN SHORT TERM EXPOSURE AND ANNOYANCE

4. Responses to Questionnaire Item 5

Respondents were requested in Item 5 to describe their annoyance with air-carrier aircraft in the year preceding each round of interviews. Figure 14 plots these data in a format identical to that of Figure 13. Figure 15 makes it clear that the weekly and yearly annoyance judgments are very similar.

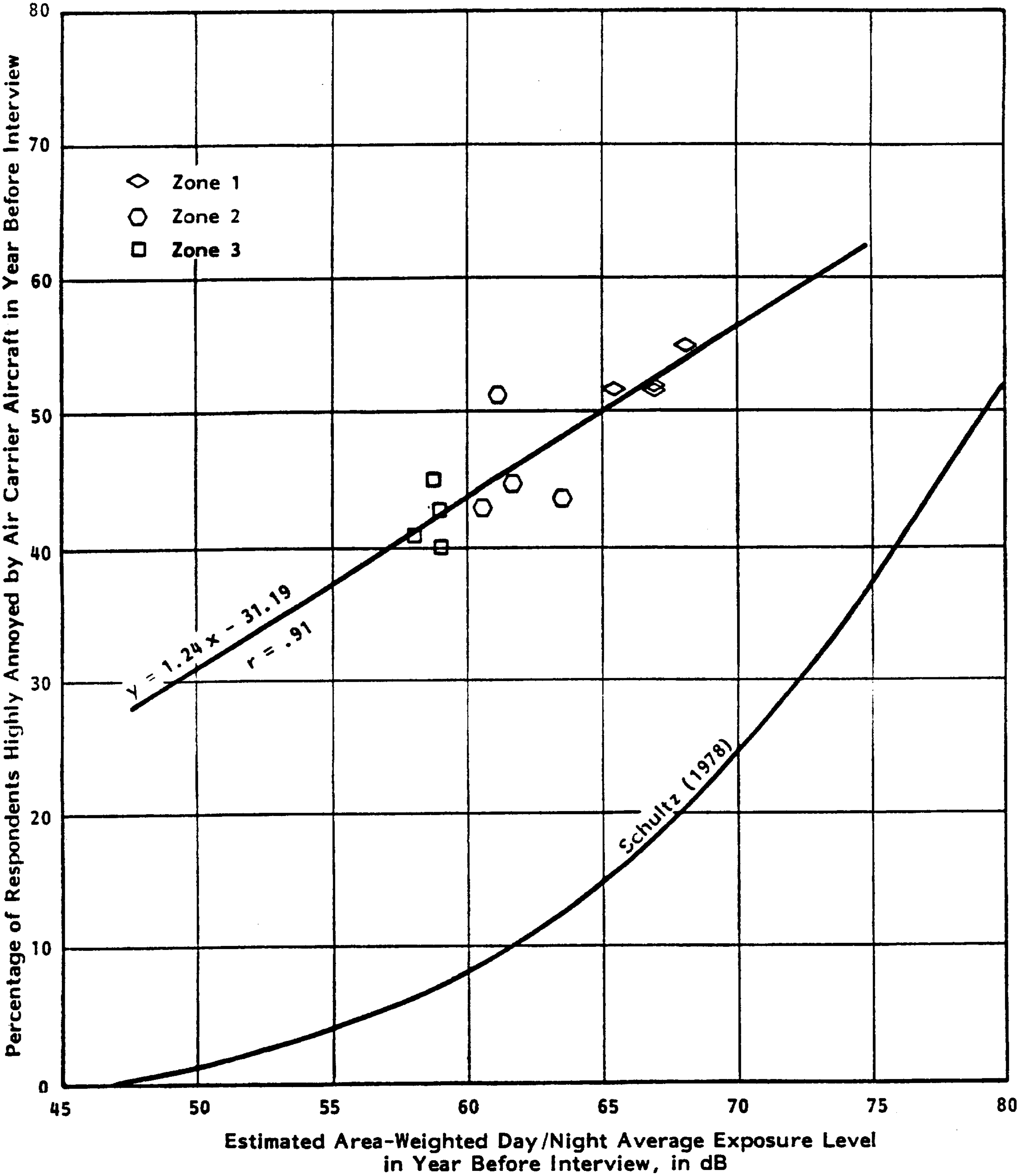


FIGURE 14. RELATIONSHIP BETWEEN LONG TERM EXPOSURE AND ANNOYANCE

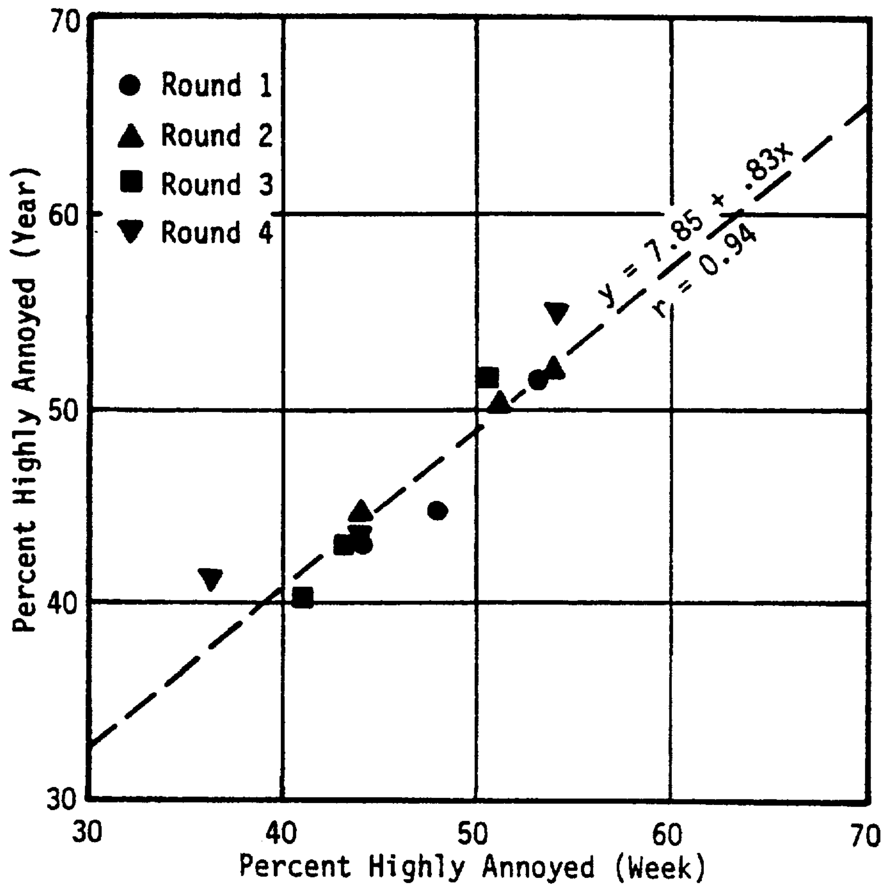


FIGURE 15. PERCENTAGES OF RESPONDENTS HIGHLY ANNOYED BY JET AIRCRAFT NOISE FOR THE WEEK AND YEAR PRECEDING INTERVIEW

IV. DISCUSSION

Figure 16 summarizes the principal findings of the current study of community response to different noise abatement departure procedures. A column of three plots is shown in the figure for each exposure zone. The top panel of each column shows estimated area-weighted noise exposure for each round of interviews. The middle and bottom panels show percentages of respondents who described themselves as highly annoyed by weekly and yearly exposure prior to each round of interviews. Ninety-five percent confidence intervals are shown for the social survey data.

It is apparent from Figure 16 that neither exposure nor annoyance changed appreciably throughout the course of the evaluation. This section examines these findings in greater detail, interprets them in the context of similar studies, seeks potential explanations for them, and explores some of their implications.

A. Further Analysis of Relationship Between Exposure and Annoyance

As is evident from the contour gradients of Figure 3, noise exposure varied by as much as 13 dB within the boundaries of exposure zones. In an effort to examine changes in annoyance in more homogeneous exposure areas, the two larger exposure zones were further subdivided.

Zone 2 was divided into eastern and western portions differing by about 5 dB in average exposure level, while zone 3 was divided into northern and southern portions differing by about 3 dB in

average exposure level. Each of the subdivisions of the exposure zones was more homogeneous in exposure than the whole zones from which they were partitioned.

Area weighted exposure estimates were then made for the subdivisions by the procedures of Appendix A, and questionnaire responses tabulated separately for respondents in each subdivision. Table IV shows these exposure estimates along with sample sizes and percentages of respondents who described themselves as highly annoyed by air-carrier aircraft noise in the weeks prior to each round of interviews (Questionnaire Item 4). Figure 17 plots the data for the subdivided zones along with corresponding information for undivided exposure zone 1.

Agreement between the data plotted in Figure 17 and Schultz's general dosage-response curve is no better than in Figure 13, which displays comparable data for the undivided exposure zones. Indeed, the statistical association between exposure and annoyance is greater for the undivided exposure zones than for the partitioned zones. Thus, it does not appear likely that heterogeneity of noise exposure within interviewing areas is a reasonable explanation for the disparity between the present findings and those of Schultz (1978).

B. Relationship of Present Findings to Others

Although the present findings do not agree well with the dosage-response relationship Schultz (1978) has synthesized, they correspond closely with the findings of Fidell, Horonjeff, Teffeteller and Pearsons (1981). Fidell et al. (1981) conducted a survey of annoyance due to changing aircraft noise

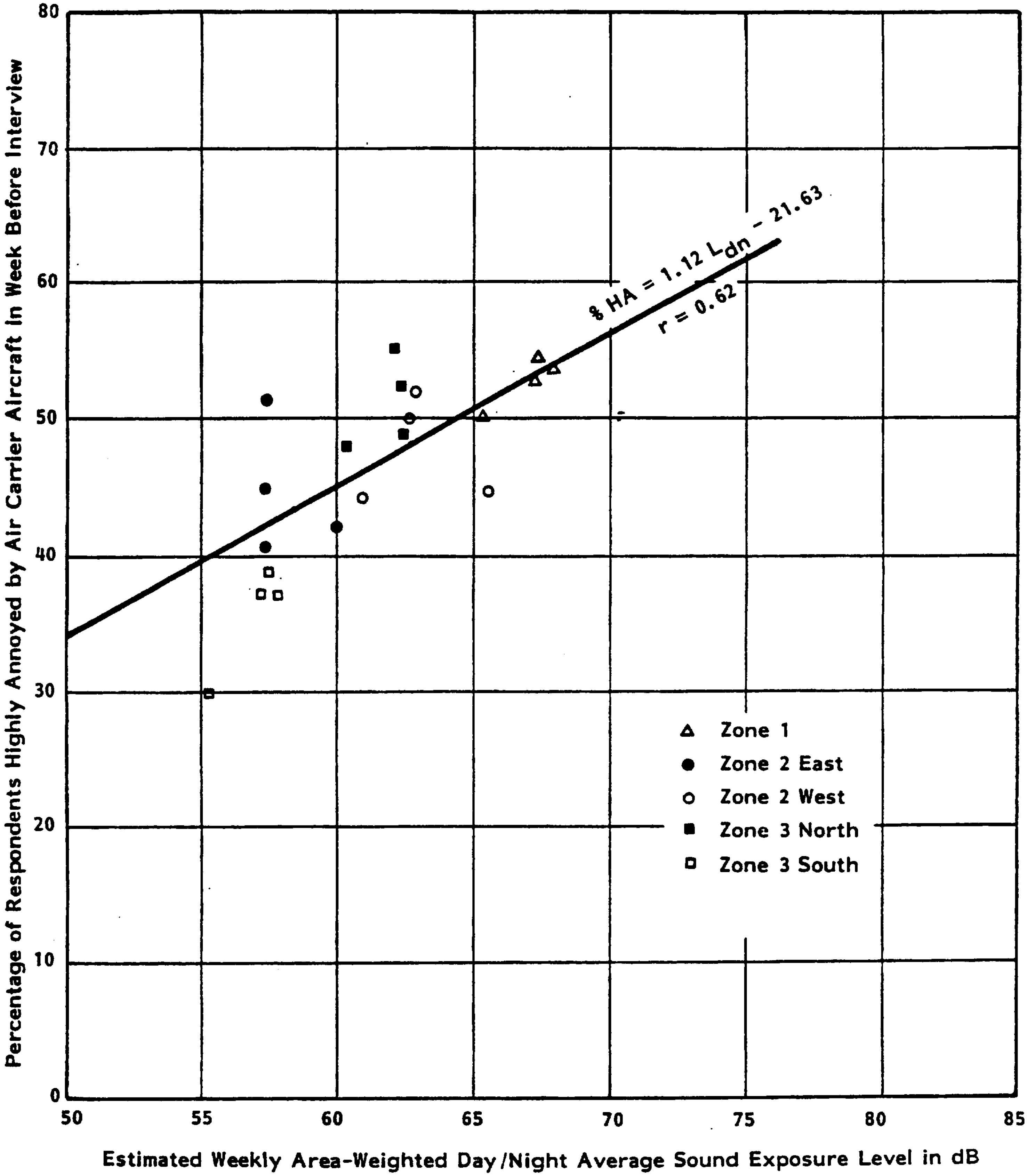


FIGURE 17. RELATIONSHIP BETWEEN WEEKLY ANNOYANCE AND EXPOSURE TO JET AIRCRAFT NOISE IN SUBDIVIDED EXPOSURE ZONES

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exposure at Hollywood-Burbank-Glendale Airport (BUR) using sampling strategies, interviewing techniques, and questionnaire items very similar to those of the present study.

Figure 18 compares the major findings about prevalence of annoyance due to aircraft noise exposure in the week preceding interviewing from the present study with the findings of Fidell et al. (1981). The data points from the two studies intermingle. Figure 19 provides a similar comparison of the relationship between yearly annoyance and noise exposure at the two airports.

Figure 20 compares both the present data and the data of Fidell et al. (1981) with similar data collected by Hall et al. (1981). The straight line through the data points is a least squares linear regression to all three data sets. The slope of the relationship between exposure and annoyance in the three combined data sets is similar to that of the two studies seen in Figure 18.

The line composed of two straight segments in Figure 20 is derived from Figure 9 of Schultz (1978), and represents a fit to Swiss data on aircraft noise annoyance in low traffic noise neighborhoods. The curved line is a best fitting line to Hall et al.'s (1981) data.

It is apparent from inspection of Figure 20 that the present data (and those of Fidell et al., 1981) are even farther displaced from Schultz's general dosage-effect relationship than are the data of Hall et al. Nonetheless, agreement among the three data sets is good.

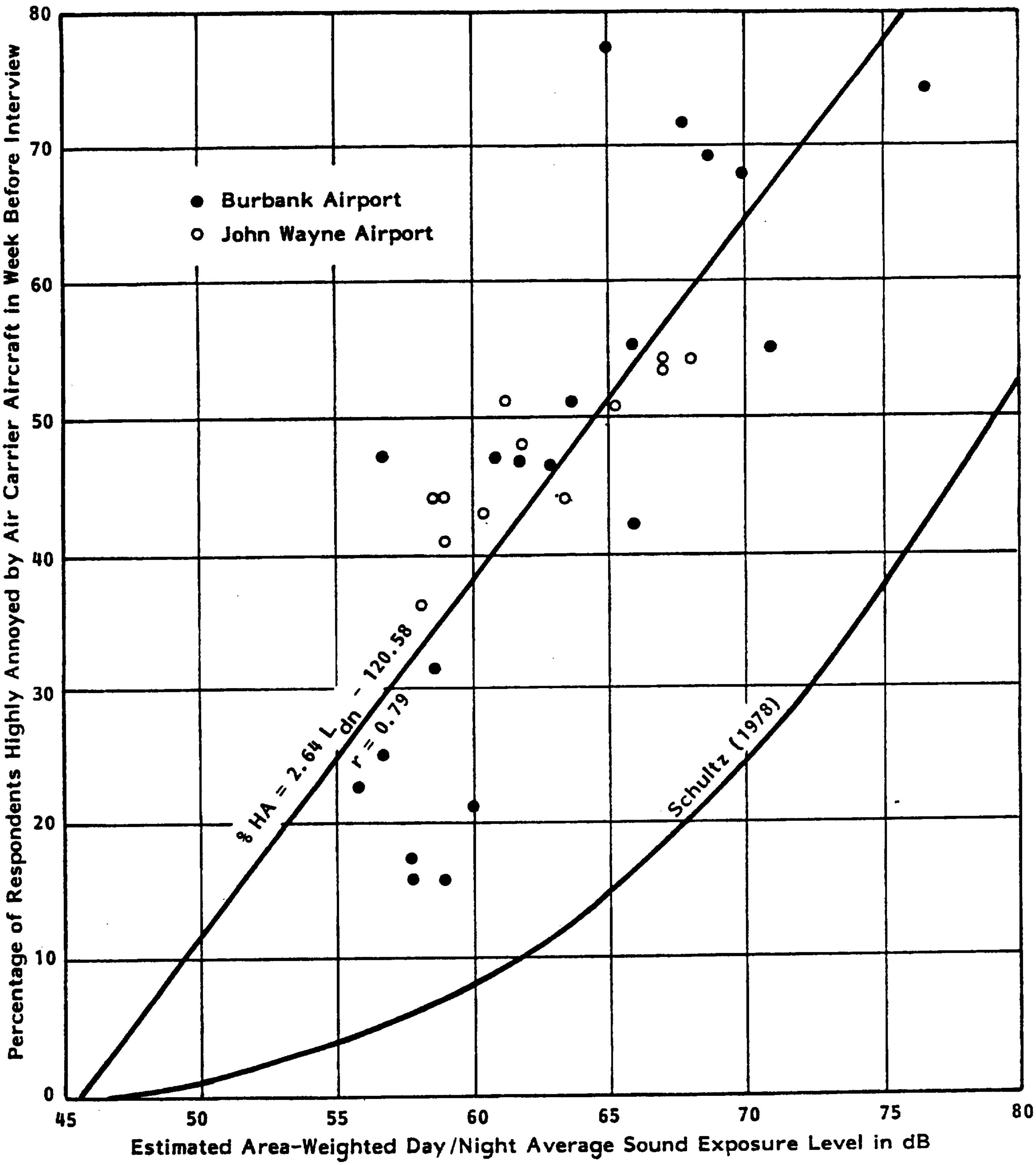

FIGURE 18. COMPARISON OF WEEKLY ANNOYANCE DATA FROM CURRENT STUDY AND FIDELL ET AL. (1981)

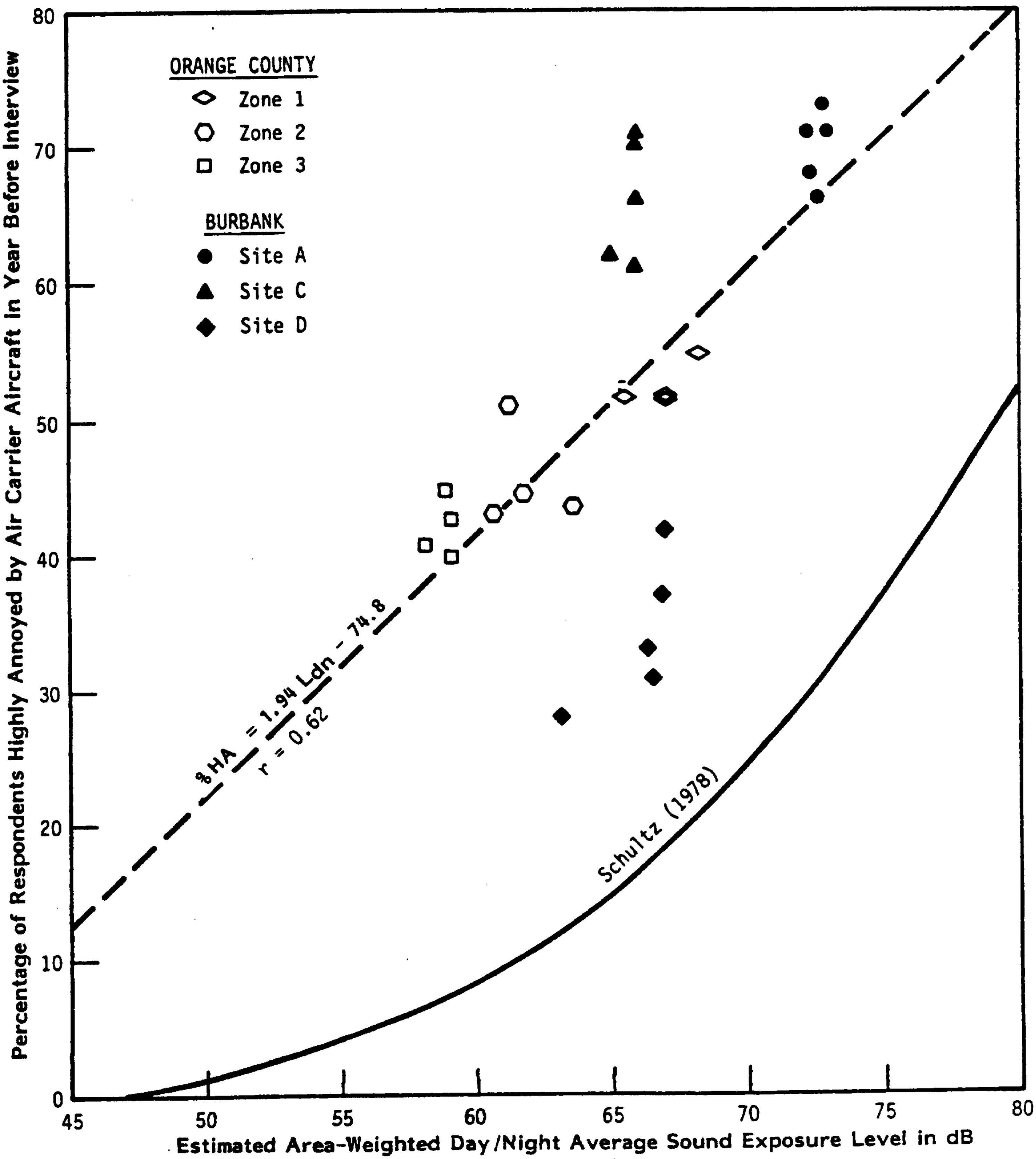

FIGURE 19. RELATIONSHIP BETWEEN PERCENTAGES OF RESPONDENTS HIGHLY ANNOYED BY JET AIRCRAFT NOISE IN YEAR PRECEDING INTERVIEW

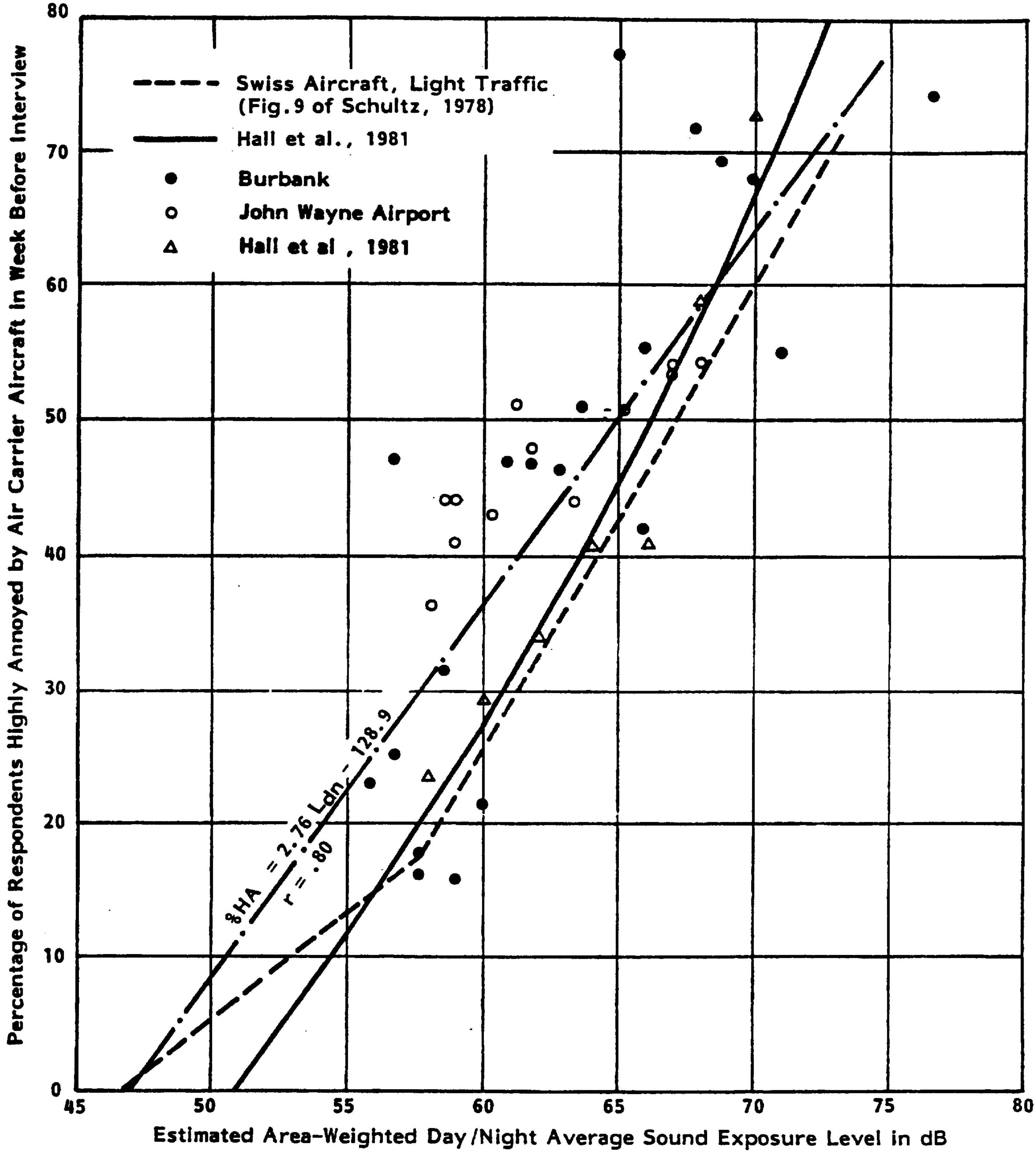

FIGURE 20. COMPARISON OF SEVERAL FITS TO THREE DATA SETS

Since the curved line of Hall et al. was developed to distinguish community response to aircraft noise from community response to surface transportation noise, some might argue that the current data (and those of Fidell et al. as well) lend support to the notion that decibel for decibel, people are more disturbed by aircraft noise than by surface transportation noise.

On the other hand, the similarity of all three data sets to the two-segment fit developed for the Swiss aircraft noise study (Grandjean et al., 1973) carries other implications. This latter relationship was developed for annoyance due to aircraft noise in communities exposed to relatively low levels of street traffic noise. The proximity of all three data sets to the Swiss relationship might merely imply that aircraft noise is more annoying when it is more detectable (i.e., heard for longer periods of time over low ambient noise levels).

C. Other Potential Interpretations of Present Findings

1. Non-Quantitative Speculation

One potential explanation for the surprising pervasiveness of high annoyance with aircraft noise at both John Wayne and Burbank Airports is the unusual degree of community awareness of airport noise problems. It would be difficult to find two other mixed use airports (those with large numbers of operations by light aircraft and small numbers of operations by air-carrier jets) with as extensive and long standing records of noise-related litigation as John Wayne and Burbank Airports.

It is at least plausible that self reports of annoyance in communities surrounding those airports are due not only to exposure

to aircraft noise, but also in part to exposure to continuing press coverage, political debate, and other forms of publicity of airport noise problems. This observation does not imply that self described annoyance is any the less genuine in a highly politicized situation than in a non-politicized one. Respondents who described themselves as "very" or "extremely" annoyed by aircraft noise in the present study undoubtedly sincerely believed themselves to be so annoyed. It is simply not known whether they would also have been so annoyed if the history of community relations with the airport had been different.

Another factor which might arguably have had some bearing on the small reductions in prevalence of annoyance attributable to reductions in aircraft noise exposure is the comparatively short duration of the exposure changes in the present evaluation. Fidell et al. (1981), analyzing differences between weekly and yearly annoyance at Burbank Airport, have suggested that community response is a process with a measurable time constant on the order of eight weeks or more. That is, asymptotic levels of annoyance are not reached until a community has been exposed to changed noise exposure conditions for a period of at least months. Since the current exposure periods lasted only two or three weeks, there is some basis for belief that the full benefit of noise reductions resulting from operational changes was not secured during the evaluation period.

It is difficult to quantify the magnitude of this effect, since existing estimates of the time constant of community annoyance are not very precise. It is doubtful, however, that major shifts in the prevalence of annoyance would have been observed if the current evaluation had continued longer, since the small

magnitude of exposure changes would limit the change in prevalence of annoyance in any event.

The greater importance of magnitude of exposure change rather than duration of exposure change in the present case can be appreciated by examination of the slope of Schultz's generalized dosage response relationship. This relationship, developed from what can only be assumed to be steady state noise exposure, has a slope of only about one to four percent increase in prevalence of annoyance per decibel of exposure in the range of interest. Thus, the asymptotic levels of annoyance in neighborhoods near John Wayne Airport probably do not lie far from the levels of annoyance actually observed following exposure changes of only one or two decibels.

2. Adequacy of Noise Metric

Since there is little reason to doubt the validity or reliability of the survey findings (see Appendix C for extensive discussion of sampling, response, and questionnaire biases), it is not unreasonable to seek explanations for the dissimilarity of the present findings from Schultz's (1978) general dosage response relationship in the measure of noise exposure. The issue is not the accuracy of John Wayne Airport's noise monitoring system, nor the area-weighting procedure used to estimate noise exposure for groups of respondents, nor the usefulness of L_{dn} as a tool for land use planning. The issue, instead, is the applicability of equivalent energy metrics for prediction of community response in noise exposure situations of the present sort.

It must first be recognized that aircraft noise exposure in neighborhoods near John Wayne Airport differs in certain regards from aircraft noise exposure at major international airports. Schultz's synthesis is based in part on data from social surveys conducted in the vicinity of large air-carrier airports, but is not based on any information about community response to noise from general aviation airports or mixed-use airports. To understand why the distinction between large air-carrier airports and mixed-use airports might affect the generality of application of the L_{dn} metric to prediction of community response to aircraft noise, it is important to understand how the metric itself is affected by the two different types of noise exposure.

The tacit assumption that underlies the use of any integrated-energy metric (L_{dn}, L_{eq}, etc.) for prediction of community response is often referred to as the "equal energy assumption". Stated simply, this assumption holds that annoyance is determined by exposure, the product of noise level and duration. Belief in this equal energy assumption implies a belief that people are equally annoyed by a small number of very high level noise events as by a large number of very low level noise events. Put another way, the equal energy assumption implies that annoyance due to the level of a noise intrusion and its duration are compensable.

Most people who subscribe to the equal energy assumption recognize that it is tenable only over a reasonable range of noise levels and durations. However, it can be persuasively argued that in many real world settings, the equal energy assumption does not require extreme tradeoffs between annoyance associated with numbers (hence, total duration), and annoyance associated with levels of noise events.

The sort of aircraft noise exposure that occurs in a neighborhood under an approach path to a major air-carrier airport is a good example of a limited need for compensation between duration and level. The air-carrier fleet operating at an airport of this type is composed in large part of a few jet aircraft types. Single event noise levels produced by flyovers in such a neighborhood rarely differ by more than a few decibels from overflight to overflight.

Situations of this type, in which L_{dn} values are determined by large numbers of similar duration, high level noise events, have been the traditional concern of aviation noise policy. It is characteristic of these situations that small changes in either numbers or single event levels of overflights do not materially affect L_{dn} values. For example, fifty flights more or less per day out of 500 daily landings at a major international airport would not change the L_{dn} in a neighborhood in the approach path by more than ± 0.5 dB. Likewise, replacement of 50 aircraft per day at this hypothetical airport with others producing single event levels 10 dB lower would have only a trivial effect on L_{dn} values in exposed neighborhoods.

Nonetheless, integrated-energy measures of noise exposure are very sensitive to infrequent, unusually high level noise events that are 10 dB or more higher in level than a great many lower level noise events. Inclusion of a few such unusual noise events in a distribution of noise levels can greatly elevate daily L_{dn} values. Because of the homogeneity of noise exposure conditions at major air carrier airports, this sensitivity

of integrated energy measures of community noise to rare high level events has not been a major problem. In fact, the insensitivity of L_{dn} measures to small changes in numbers or levels of aircraft operations at major airports supports the common belief that no substantial relief for aircraft noise-exposed communities can be expected from minor operational changes (flight profiles, schedule or equipment restrictions, etc.)*.

Now consider the nature of noise exposure at mixed-use airports. Figure 21, reproduced from Fidell et al. (1981, Figure D-1) shows the bimodal distribution of maximum A-Weighted sound levels due to aircraft noise during a one week period in a neighborhood near a mixed-use airport. The overflights responsible for the noise levels in the vicinity of 100 dBA were by scheduled air-carrier jets (approximately 50 per day). The overflights responsible for the noise levels ten to thirty decibels lower were by small piston engine aircraft (roughly 600 per day).

The equal energy assumption has some distinctly different implications in this latter case than in the case of a major air carrier airport. Figure 22 helps to illustrate the contrast between the two sorts of noise exposure. The family of curves in Figure 22 shows how many operations by aircraft types producing higher noise levels suffice to control L_{dn} values in neighborhoods exposed to both higher- and lower-level overflight noise. The curves are parametric in $\Delta\overline{SEL}$, the average difference in level between the higher and lower level aircraft.

Applying the relationship shown in Figure 22 to the 25 dB approximate difference in average levels between air-carrier

*Note, however, that small changes in exposure can greatly affect the size of impacted populations within contours in densely settled airport neighborhoods.

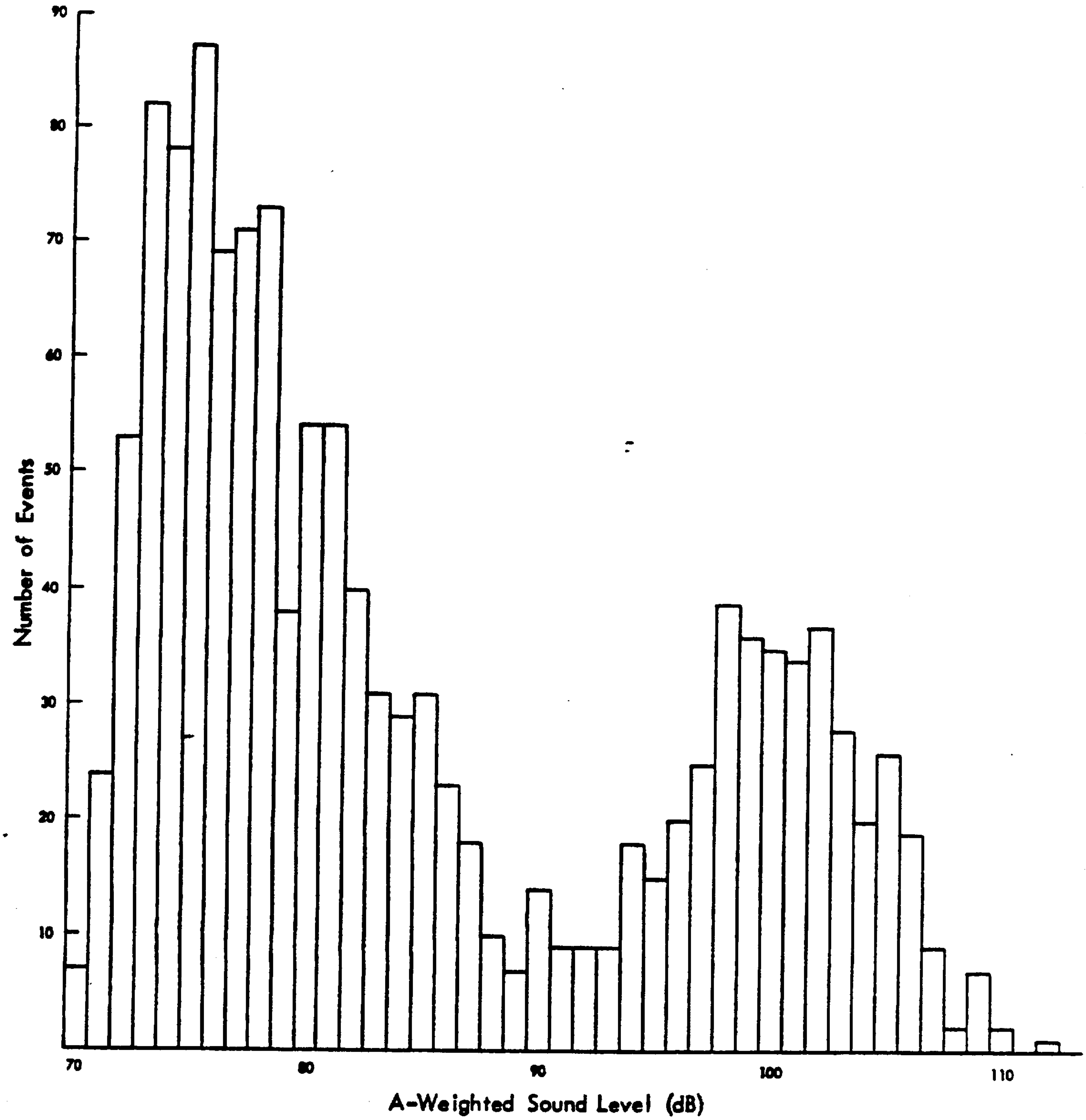

FIGURE 21. DISTRIBUTION OF MAXIMUM A-WEIGHTED AIRCRAFT OVERFLIGHT SOUND LEVELS FOR ONE NEIGHBORHOOD NEAR BURBANK AIRPORT

jets and general aviation propeller aircraft apparent in Figure 21, it can be seen that the 600-odd general aviation operations per day in the neighborhood in question contribute virtually nothing to the L_{dn} value established by the air carrier-jets. The fifty jet operations in the neighborhood would control the L_{dn} value of the neighborhood's aircraft noise exposure to within 1 dB even if there were 4000 general aviation operations daily! In fact, as few as eight jet operations per day would suffice to control the L_{dn} value of the exposure produced by the 600 daily operations by light piston engine aircraft.

Strict belief in the equal energy assumption in this case would lead to the prediction that general aviation operations at the airport in question could increase sevenfold without any increase in annoyance due to aircraft noise exposure. Even ignoring limits to the airport's carrying capacity, such a prediction is clearly implausible. Thus, caution is in order when use is made of a noise metric such as L_{dn} to predict community response to distributions of noise exposure that differ greatly from those for which Schultz's (1978) dosage-effect relationship was derived.

There is no lack of alternate measures of aircraft noise with which community response to exposure can be predicted with varying degrees of success. The fundamental problem, however, is one of understanding rather than one of measurement. The limits to the equal energy hypothesis, and the utility of metrics other than integrated energy ones, will not be fully appreciated until scientific understanding of the origins of community annoyance is more advanced.

ACKNOWLEDGEMENTS

Cooperation from the airlines that operate turbojet aircraft at John Wayne Airport and from the airport management was instrumental in conducting the present study. The authors are also grateful to colleagues at BBN (notably Drs. William Galloway and Theodore Schultz) and to Mr. James Densmore of FAA for technical discussions and information provided in the course of this study. Thanks are due to airport-area residents for their repeated willingness to express their opinions.

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Step 3) NOISEMAP was exercised with the revised input information to compute L_{dn} contours at 1 dB intervals. These contours were overlaid on interviewing areas (see Figure 3). Approximate areas enclosed within each 1 dB contour interval were then determined. The approximation was made by measuring lengths parallel to contour lines. This approximation was justified by the observation that the spacing between contours was approximately equal within each interviewing area. Because residential housing within interviewing areas was on a regular grid of streets, and because indi-dividual lot sizes varied little, this area weighting procedure was tantamount to a population weighting procedure as well.

Step 4) An "area-weighted" L_{dn} for each interviewing area was then computed as in EQ. 1 below:

$$\text{Area-weighted } L_{dn} = 10 \log \frac{\sum_{i=1}^{N} L_i \, 10^{\frac{D_i}{10}}}{\sum_{i=1}^{N} L_i}, \quad \text{Eq. A-1}$$

where L_i is the length of the contour segment within an interviewing area and D_i is the L_{dn} at the mid-point of the segment.

Step 5) Final adjustments were made to the computed area-weighted figures to reflect actual measured L_{dn} values during each departure procedure evaluation period. The adjustment was based on the observed difference between computed and measured L_{dn} values at individual

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microphone locations. Where more than one microphone position was near the boundaries of an interviewing area, an average difference between actual and predicted L_{dn} values was used for the final adjustment.

APPENDIX B

RESULTS OF INTERVIEWING

This Appendix contains the following tabulations of interview data:

Round 1: 4-6 September 1981

	Zone 1	Zone 2	Zone 3	Total
Completed Interviews	202	195	205	602
Non-Sample:				
Tel. Out of Service	19	4	10	33
Wrong Address	15	5	17	37
Ineligible Respondent	1	1	3	5
Non-Responses:				
Unreached (5 attempts)	45	41	62	148
Refusal/Language	39	36	56	131

Round 2; 18-20 September 1981

	Zone 1	Zone 2	Zone 3	Total
Completed Interviews	270	259	256	785
Non-Sample:				
Tel. Out of Service	31	19	16	66
Wrong Address	15	3	17	35
Ineligible Respondent	7	8	16	31
Non-Responses:				
Unreached (5 attempts)	43	59	80	182
Refusal/Language	54	53	59	166

Round 3: 9-11 October 1981

	Zone 1	Zone 2	Zone 3	Total
Completed Interviews	323	336	332	991
Non-Sample:				
Tel. Out of Service	35	3	32	70
Wrong Address	30	19	32	81
Ineligible Respondent	7	9	14	30
Non-Responses:				
Unreached (5 attempts)	58	45	109	212
Refusal/Language	53	57	75	185

Round 4: 30 October-1 November 1981

	Zone 1	Zone 2	Zone 3	Total
Completed Interviews	257	241	229	727
Non-Sample:				
Tel. Out of Service	35	12	21	68
Wrong Address	19	17	20	56
Ineligible Respondent	5	4	11	20
Non-Responses:				
Unreached (5 attempts)	48	25	62	135
Refusal/Language	40	61	46	147

TABLE B-1: ACCOUNTING OF RESPONDENT CONTACTS IN FOUR ROUNDS OF INTERVIEWING

	Zone 1	Zone 2	Zone 3
Round 1	71	72	64
Round 2	73	70	65
Round 3	74	77	64
Round 4	74	74	68

TABLE B-2: RATIOS OF COMPLETED INTERVIEWS TO NON-RESPONSE CONTACTS, IN PERCENT

	Zone 1			
Round	1	2	3	4
L_{dn}	67	67	65	68
NAA	0.74	0.70	0.75	0.72
SLI	0.09	0.10	0.07	0.10
MOD	0.09	0.09	0.07	0.11
VERY	0.03	0.07	0.04	0.04
EXT	0.03	0.04	0.05	0.03
UNK	0.01	----	----	----
*HIGHLY	0.06	0.11	0.09	0.07

	Zone 2			
Round	1	2	3	4
L_{dn}	62	63	61	63
NAA	0.78	0.71	0.79	0.77
SLI	0.08	0.08	0.06	0.07
MOD	0.07	0.11	0.07	0.08
VERY	0.03	0.07	0.04	0.04
EXT	0.04	0.03	0.03	0.03
UNK	----	----	----	----
*HIGHLY	0.07	0.10	0.07	0.07

	Zone 3			
Round	1	2	3	4
L_{dn}	59	59	59	58
NAA	0.70	0.72	0.79	0.83
SLI	0.12	0.09	0.09	0.07
MOD	0.08	0.08	0.07	0.07
VERY	0.04	0.06	0.04	0.02
EXT	0.03	0.03	0.02	0.01
UNK	0.01	----	----	----
*HIGHLY	0.07	0.09	0.06	0.03

*Highly = Very + Extremely.

TABLE B-3. SUMMARY OF ANNOYANCE AND NOISE DATA FOR FOUR ROUNDS OF INTERVIEWS - QUESTIONNAIRE ITEM 2

Zone 1				
Round	1	2	3	4
L_{dn}	67	67	65	68
NAA	0.42	0.41	0.44	0.45
SLI	0.13	0.14	0.14	0.12
MOD	0.14	0.20	0.21	0.18
VERY	0.14	0.12	0.09	0.13
EXT	0.14	0.11	0.11	0.11
UNK	0.01	----	----	----
*HIGHLY	0.28	0.23	0.20	0.24

Zone 2				
Round	1	2	3	4
L_{dn}	62	63	61	63
NAA	0.47	0.48	0.53	0.46
SLI	0.17	0.12	0.11	0.21
MOD	0.19	0.15	0.16	0.17
VERY	0.10	0.15	0.09	0.08
EXT	0.06	0.09	0.09	0.06
UNK	----	----	0.01	0.02
*HIGHLY	0.16	0.24	0.18	0.14

Zone 3				
Round	1	2	3	4
L_{dn}	59	59	59	58
NAA	0.73	0.71	0.73	0.77
SLI	0.12	0.07	0.12	0.10
MOD	0.06	0.13	0.11	0.09
VERY	0.02	0.03	0.03	0.00
EXT	0.02	0.04	0.02	0.02
UNK	0.01	----	----	0.01
*HIGHLY	0.04	0.07	0.05	0.02

*Highly = Very + Extremely.

TABLE B-4: SUMMARY OF ANNOYANCE AND NOISE DATA FOR FOUR ROUNDS OF INTERVIEWS QUESTIONNAIRE ITEM 3

Zone 1				
Round	1	2	3	4
L_{dn}	67	67	65	68
NAA	0.12	0.15	0.17	0.19
SLI	0.11	0.11	0.11	0.05
MOD	0.22	0.19	0.21	0.20
VERY	0.14	0.19	0.17	0.19
EXT	0.39	0.36	0.33	0.35
UNK	0.01	----	----	----
*HIGHLY	0.53	0.55	0.50	0.54

Zone 2				
Round	1	2	3	4
L_{dn}	62	63	61	63
NAA	0.18	0.22	0.26	0.23
SLI	0.16	0.11	0.13	0.12
MOD	0.18	0.15	0.17	0.19
VERY	0.22	0.16	0.18	0.14
EXT	0.26	0.35	0.24	0.29
UNK	----	----	----	----
*HIGHLY	0.48	0.51	0.42	0.43

Zone 3				
Round	1	2	3	4
L_{dn}	59	59	59	58
NAA	0.21	0.27	0.29	0.30
SLI	0.16	0.09	0.13	0.15
MOD	0.17	0.18	0.16	0.17
VERY	0.22	0.16	0.15	0.14
EXT	0.22	0.28	0.26	0.23
UNK	----	----	----	0.01
*HIGHLY	0.44	0.44	0.41	0.37

*Highly = Very + Extremely.

TABLE B-5: SUMMARY OF ANNOYANCE AND NOISE DATA FOR FOUR ROUNDS OF INTERVIEW QUESTIONNAIRE ITEM 4

	Zone 1			
Round	1	2	3	4
L_{dn}	67	67	65	68
NAA	0.12	0.10	0.12	0.13
SLI	0.09	0.10	0.09	0.06
MOD	0.18	0.16	0.13	0.16
VERY	0.20	0.20	0.18	0.19
EXT	0.31	0.32	0.33	0.36
UNK	----	0.01	----	----
*HIGHLY	0.51	0.52	0.51	0.55

	Zone 2			
Round	1	2	3	4
L_{dn}	62	63	61	63
NAA	0.14	0.16	0.20	0.17
SLI	0.15	0.09	0.11	0.11
MOD	0.21	0.18	0.19	0.22
VERY	0.20	0.16	0.17	0.13
EXT	0.25	0.34	0.26	0.30
UNK	----	----	----	----
*HIGHLY	0.45	0.50	0.43	0.43

	Zone 3			
Round	1	2	3	4
L_{dn}	59	59	59	58
NAA	0.16	0.23	0.20	0.20
SLI	0.18	0.08	0.13	0.14
MOD	0.19	0.16	0.17	0.16
VERY	0.18	0.16	0.15	0.15
EXT	0.25	0.29	0.26	0.26
UNK	----	----	----	----
*HIGHLY	0.43	0.45	0.41	0.41

*Highly = Very + Extremely.

TABLE B-6: SUMMARY OF ANNOYANCE AND NOISE DATA FOR FOUR ROUNDS OF INTERVIEWS QUESTIONNAIRE ITEM 5

APPENDIX C

SUPPLEMENTARY ANALYSES

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SUPPLEMENTARY ANALYSES

This Appendix contains a number of analyses of the social survey data that do not deal directly with the evaluation of community response to different departure procedures, but rather with procedural and secondary matters concerning the validity and reliability of the survey.

A. Analysis of Sampling Bias*

1. Disproportionate Representation

As is always the case in survey research, it is only the attitudes of respondents that are known. If there were good reason to believe that non-respondents as a group held different attitudes about aircraft noise than respondents, there might be reason to question the degree to which opinions reported in the text of this report represented the opinions of the community as a whole. Since the actual opinions of non-respondents are unknown, the only basis for such an argument is an a priori appeal to differences in some other attributes of non-respondents as a group that might influence their opinions.

a. Socioeconomic Differences Between Sample and Community

The most often invoked appeal is to demographic differences, particularly socioeconomic ones. This argument has poor face

*This section paraphrases portions of Fidell, Horonjeff, Schultz, and Teffeteller (1982).

validity in the presence instance for several reasons. First, there is little reason to believe that aircraft noise exposure differs meaningfully for richer or poorer, better or less well-educated members of households within each of the current exposure zones.

Second, there is little reason to believe that annoyance due to noise exposure is related to socioeconomic variables. Although non-physical factors may play a substantial role in complaint behavior, there is no evidence to suggest that supersensitive or imperturbable people tend to be concentrated in particular socioeconomic groups. If personality and other factors that might arguably affect annoyance occur randomly throughout the population, there is no basis for arguing that the current sample is biased by systematically under or over-representing the opinions of supersensitive or imperturbable population fractions.

Third, the sampling strategy made it unlikely that any large sub-class of neighborhood residents could have been systematically excluded from contributing their opinions. Interviewing was not conducted haphazardly within communities, but rather within carefully delineated and relatively homogeneous neighborhoods. It is difficult, for example, to make a credible case for substantial differences in lifestyles or socioeconomic levels among many residents in tract housing within the current interviewing areas.

b. Overrepresentation of Women's Opinions

The proportions of male and female respondents in the current survey (.38 and .62, respectively) differed appreciably from the population proportions in the exposure zones. The customary way of estimating the effects on conclusions of such known errors of representation is to recalculate survey findings on the worst case assumption that additional interviews with under-represented respondents would have yielded opinions just like those of the group who actually did contribute data to the sample. An example of such a recalculation will demonstrate that the over-representation of women in the present sample had no meaningful effect on the major findings of this survey.

The major analyses of the text of this report concerns opinion expressed in Questionnaire Item 4 (annoyance with air-carrier aircraft in the week prior to an interview). Over all four rounds of interviews and all exposure zones, 47.3% of all respondents described themselves as highly ("very" or "extremely") annoyed. Of the 1437 respondents who described themselves as highly annoyed, 513 were male and 924 were female. If the current sample had included 50% male opinion rather than 38%, an additional 352 interviews would have been conducted with male respondents (and, of course, 352 fewer interviews would have been conducted with female respondents).

Assuming that these hypothetical interviews with additional male respondents yielded the same proportion of high annoyance as did the interviews actually conducted with male respondents, an additional 154 men would have described themselves as highly annoyed. Refiguring the overall percentage of high annoyance with this increased number of male respondents (and a compensatory removal of 173 highly annoyed women from the sample) would yield an overall percentage of high annoyance in the total sample of 46.7%.

For present purposes, there is no meaningful difference between an overall annoyance figure of 47.3% (the actual sample) and 46.7% (a hypothetical sample with a balanced sex ratio). Alternate methods of adjusting the current sample for sex ratios more representative of those in the airport area (e.g., within each interviewing area separately, or by round of interview, etc.) would yield the same conclusion: the over-representation of women's opinions in the current sample had no bearing on the substantive findings. Men and women simply do not differ enough in their opinions about the annoyance of aircraft noise to make any practical difference in a study of relative annoyance of several departure procedures.

c. Disproportionate Representation of Often-at-Home Respondents

The opinions of the often-at-home are almost always more fully represented than those of the seldom-at-home in residential surveys. In many suburban communities nationwide, it is working men who are least likely to be home for interviewing. (It was for this reason that interviewing continued over weekends, when the likelihood of obtaining interviews with working members of the community would be greater than on weekdays.)

Besides, it is not clear that over-representation of the opinions of the frequently-at-home should be viewed as a bias in any event.* If this is the segment of the population (housewives, retired people, and others who do not regularly leave their homes for long periods of time during the day) that is most

*Likewise, selection for interviewing of the first adult household member to answer the telephone can only be construed as a sampling bias if one has reason to believe that sensitivity to aircraft noise varies systematically with the likelihood of answering the telephone.

affected by aircraft noise, then it could equally well be argued that their opinions are correspondingly more useful for evaluation of community response.

Five contact attempts were successful in completing interviews at sizeable fractions of households in every exposure zone. Thus, even the opinions of neighborhood residents who were seldom at home were represented to some degree. Figure C-1 shows that very few additional interviews would have been completed if additional callback attempts had been made.

An appreciation for the bias that would have resulted from failure to pursue five contacts per interview may be gained from Figure C-2. The figure shows a systematic decrease in the sample proportion highly annoyed by aircraft noise in the week preceding interviewing as a function of increasing numbers of contact attempts to achieve completed interviews.

This trend cannot be attributed exclusively to the amount of time spent at home, since the ratio of female to male respondents also decreases with increasing numbers of contact attempts.

2. Under-representation of Newcomers to Neighborhoods

Because people are always moving in and out of neighborhoods, sampling frames used at the beginning of a study several months in duration are less than current by the end of the study. If opinions about aircraft noise exposure are a function of duration of neighborhood residence, one might posit some bias attributable to the age of the sampling frame.

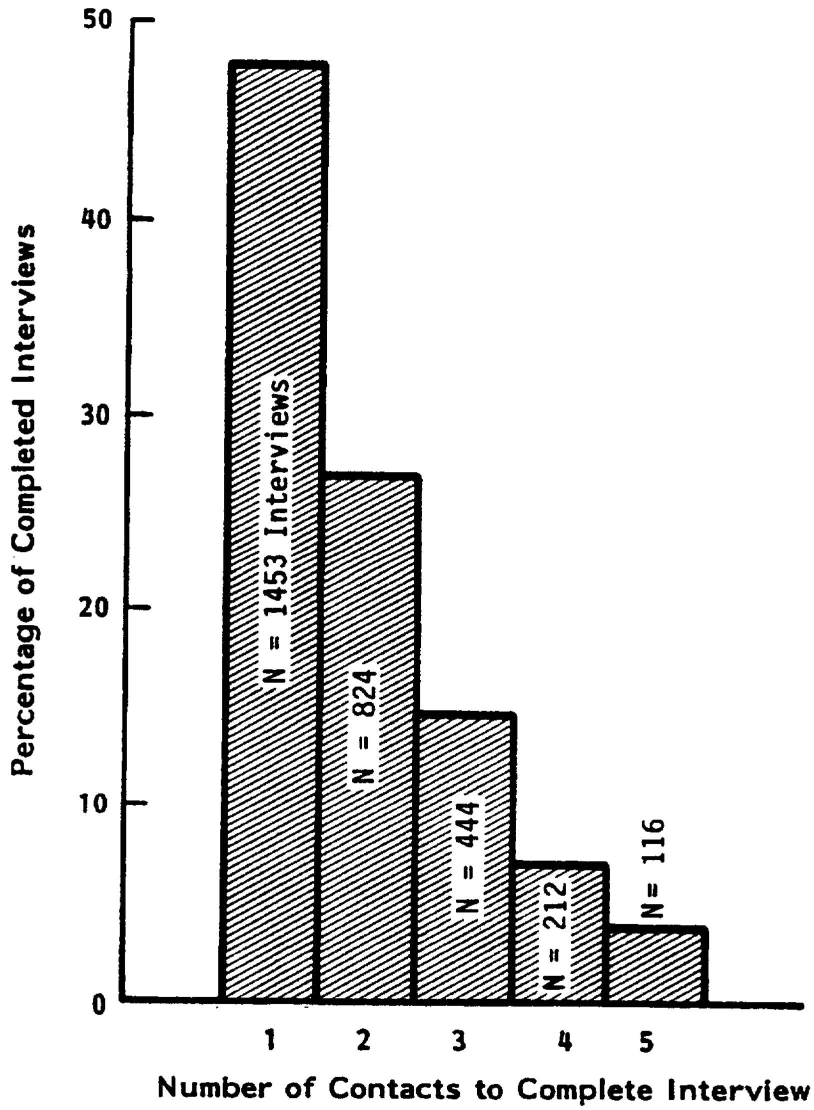

FIGURE C-1. PERCENTAGES OF COMPLETED INTERVIEWS AS A FUNCTION OF REPEATED CONTACT ATTEMPTS

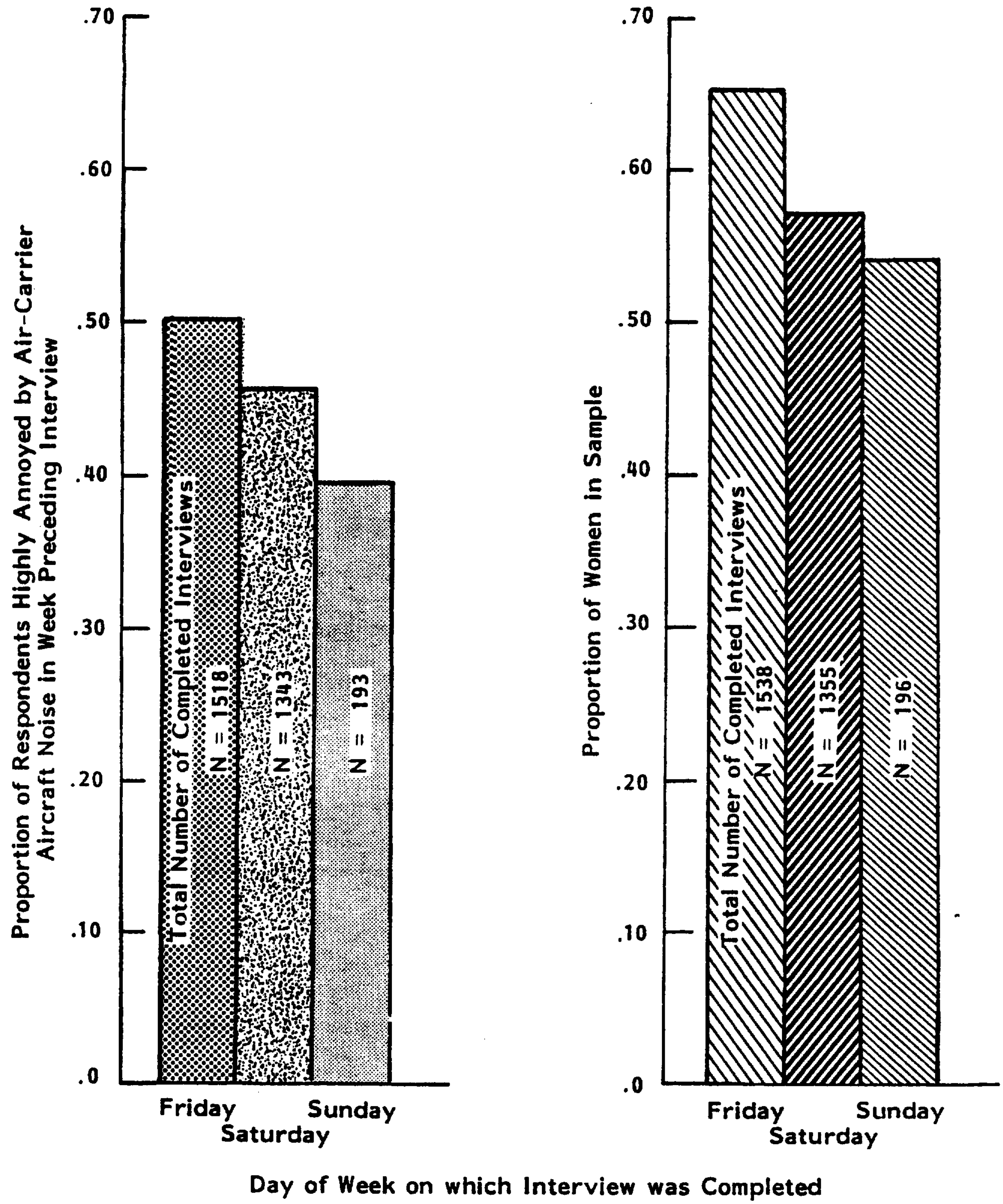

FIGURE C-2. COMPARISON OF HIGH ANNOYANCE (QUESTIONNAIRE ITEM 4) AND PROPORTION OF WOMEN IN SAMPLE BY DAY OF INTERVIEW (ALL EXPOSURE ZONES AND INTERVIEW ROUNDS)

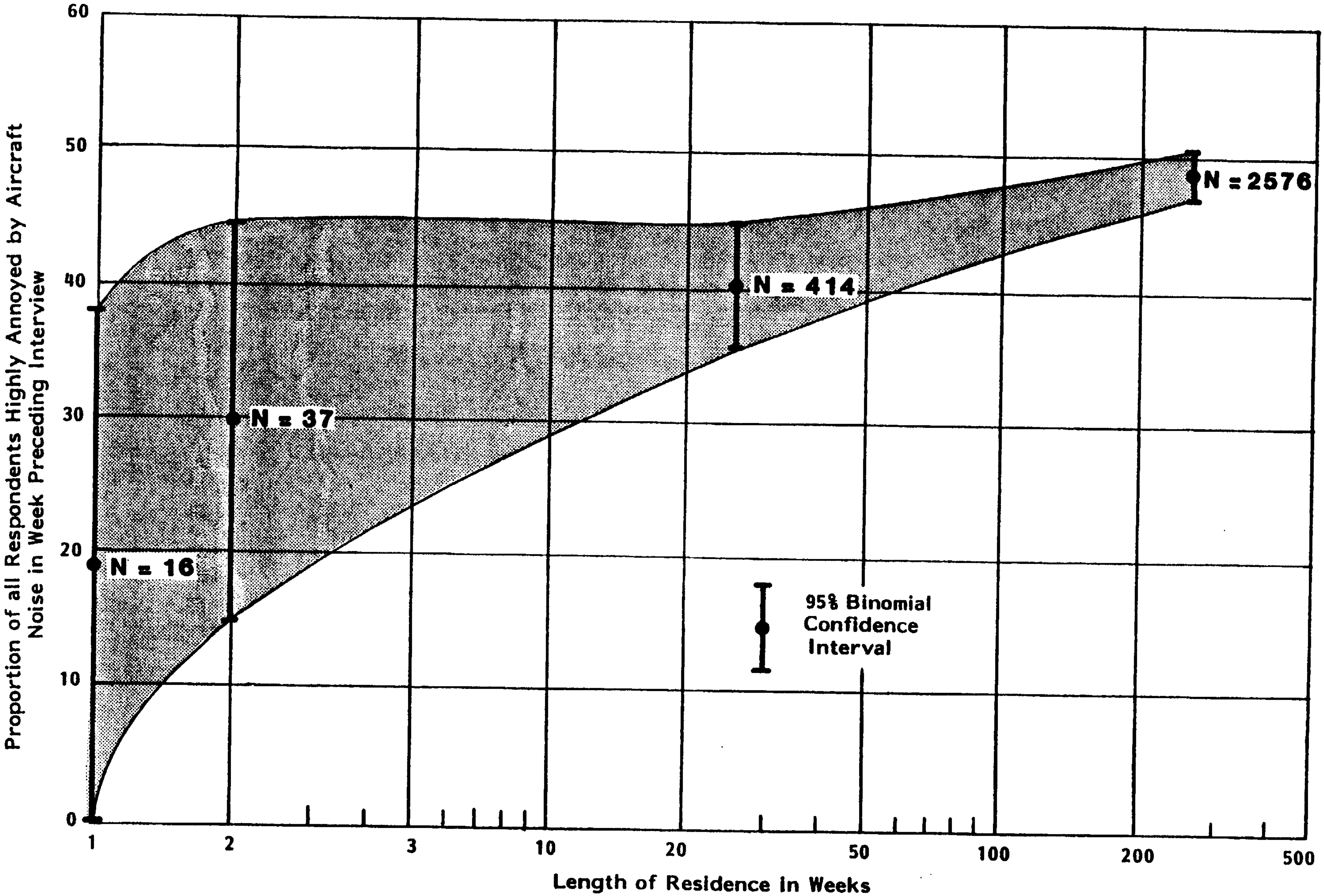

FIGURE C-3. RELATIONSHIP BETWEEN DURATION OF RESIDENCE AND PROPORTION OF RESPONDENTS HIGHLY ANNOYED BY AIRCRAFT NOISE IN WEEK PRECEDING INTERVIEW

Figure C-3 presents some weak evidence that suggests a relationship between duration of residence and annoyance with aircraft noise. The more recent neighborhood residents (of whom there are very few in this sample) appear to be less annoyed by aircraft noise than longer term residents (who form the great bulk of the respondents in this survey).

The implications of this trend for the current data set are negligible for several reasons. First, aviation policy decisions are long term ones, made for the benefit of the bulk of a community. Transient opinions of neighborhood newcomers cannot affect such decisions to the same degree as stable opinions of long term residents. Second, unless migration rates in the study areas changed dramatically between interviewing rounds, the relative effects of different departure procedures would not have been affected by differences of opinion associated with duration of residence. Third, the communities in question are fairly stable ones, whose populations are dominated by long term residents. It is doubtful that a sampling frame more recent than the August, 1981 reverse telephone directory would have revealed substantial population shifts between interviewing rounds.

B. Analysis of Response Bias

1. Order of Mention of Response Alternatives

Two forms of the Questionnaire were administered: one in which the category labels for annoyance judgments were mentioned in ascending order of severity of annoyance ("not at all" ... "extremely") and one in which the category labels were mentioned in descending order ("extremely" ... "not at all"). Half of the interviews were conducted with each form.

Figure C-4 shows response distributions for all survey respondents' annoyance judgments to Questionnaire Item 4 in all exposure zones and all interview rounds. None of differences between category judgments of annoyance for the 1500-odd respondents presented with response alternatives in ascending order of severity of annoyance differed significantly from the judgments of the 1500-odd respondents questioned in the opposite order. These data demonstrate clearly that the order of mention of response categories for the annoyance scale used in the present study did not bias questionnaire responses.

2. Internal Consistency of Opinion

One check on the reliability of self reports of degree of annoyance with aircraft noise exposure is the stability of the respondent's annoyance expressed in response to Questionnaire Items 4 and 5. The former inquires about annoyance during the past week; the latter about annoyance during the past year. Since in fact exposure during the interviewing period changed only slightly, response distributions for the two questions could be expected to be similar. Further, the *same* respondents who described themselves as highly annoyed in response to one question could also be expected to describe themselves as highly annoyed in response to the other question.

Figure C-5 shows that indeed, the overwhelming bulk of respondents who were highly annoyed by aircraft noise exposure in the week preceding an interview were also highly annoyed by aircraft noise exposure over the previous year. The figure is a graphical presentation of a crosstabulation of numbers of respondents describing their annoyance with weekly and yearly

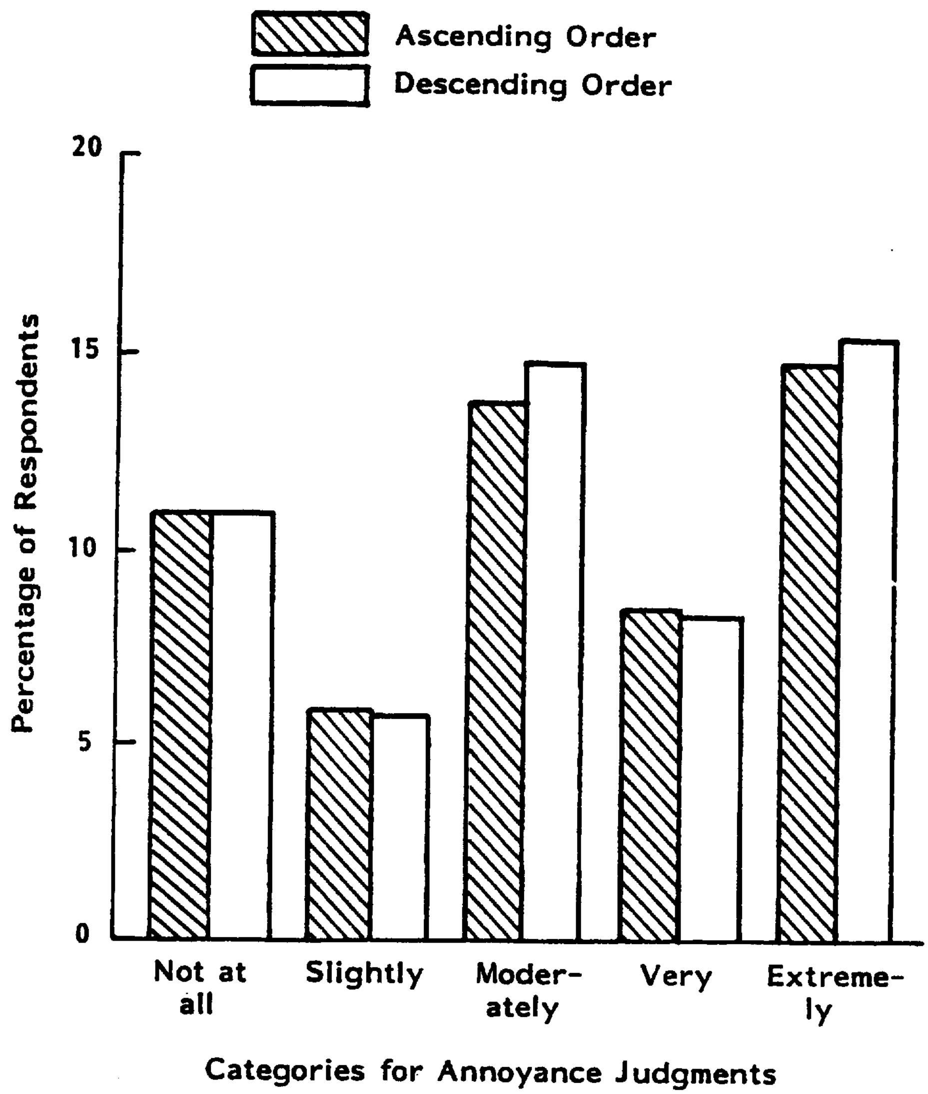

FIGURE C-4. COMPARISON OF RESPONSE DISTRIBUTIONS FOR QUESTIONNAIRE ITEM 4 IN TWO ORDERS OF PRESENTATION OF RESPONSE ALTERNATIVES

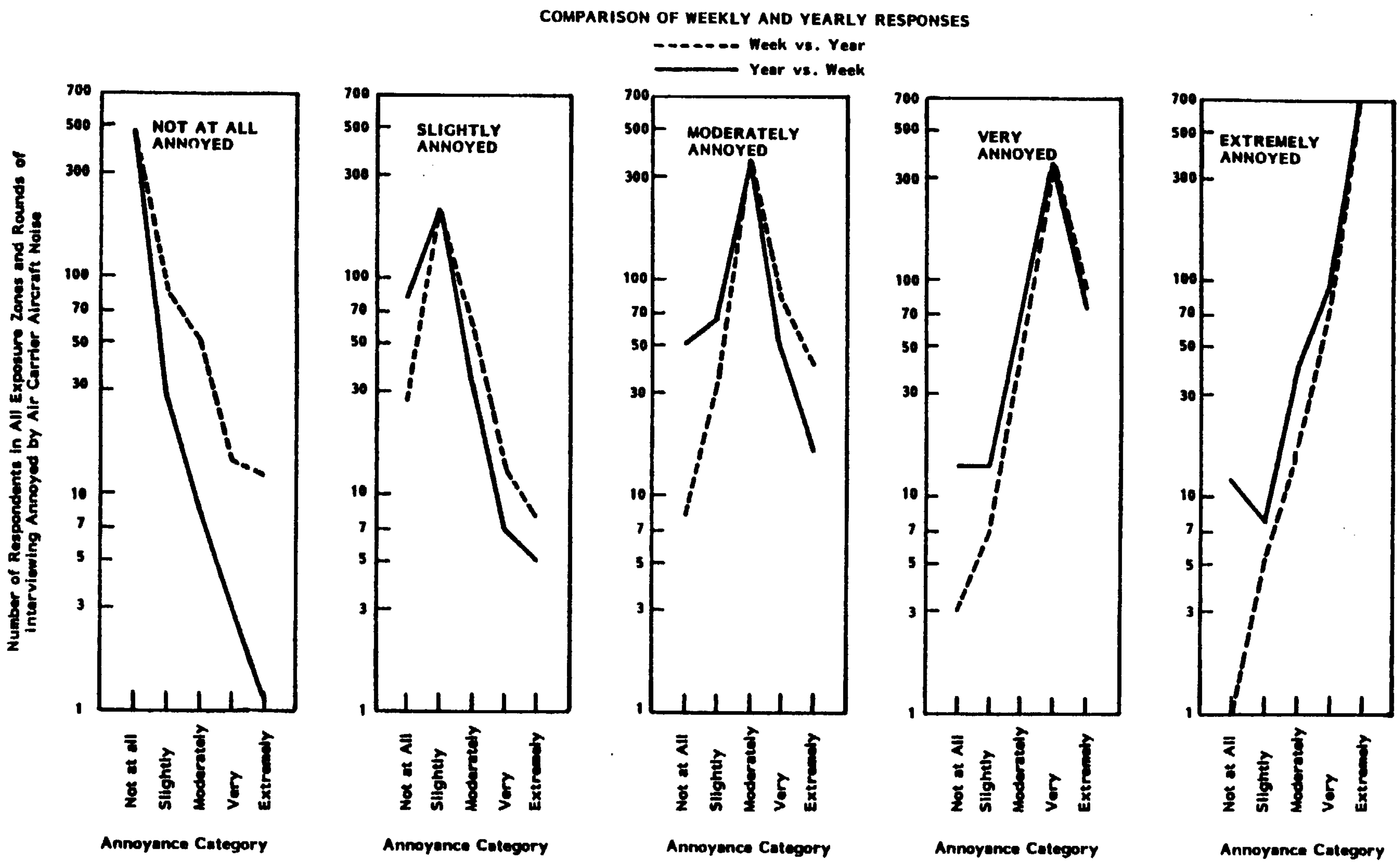

FIGURE C-5. COMPARISON OF DISTRIBUTIONS OF WEEKLY AND YEARLY ANNOYANCE aircraft noise exposure in each of five categories. Those who described their weekly and yearly annoyance in identical categories form the peak of each panel in Figure C-5. The steep descent from the peak to adjacent categories of annoyance indicates that few respondents chose terms more than one category removed from weekly annoyance to describe yearly annoyance (and vice versa).

A slight trend may be observed in Figure C-5 among respondents who did not choose identical terms to describe weekly and yearly annoyance for weekly annoyance to be described as more intense than yearly annoyance. Since exposure during the two time intervals did not differ greatly, the trend might be interpreted as an indication of a forgetting or forgiving of annoyance long past.

3. Effect of Repeated Interviewing

It is sometimes alleged that the mere conduct of interviewing can exacerbate community reaction to noise exposure. There is no support for such an allegation in the present data set (four sets of interviews with more than 3,000 respondents within about 60 days). Opinions expressed about annoyance due to noise exposure showed no trend toward increased severity of annoyance in the course of the present study. Furthermore, there is no persuasive evidence in complaint records of any systematic trend.